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Tech Notes

March 1989

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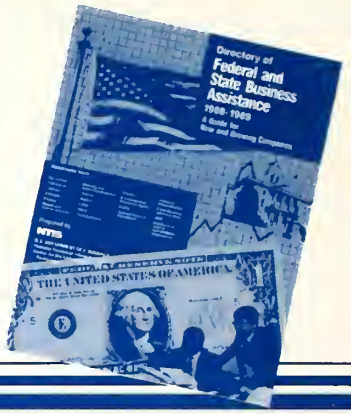

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Tech Notes

Highlighting Selected U.S. Government Technology & Resources

March 1989

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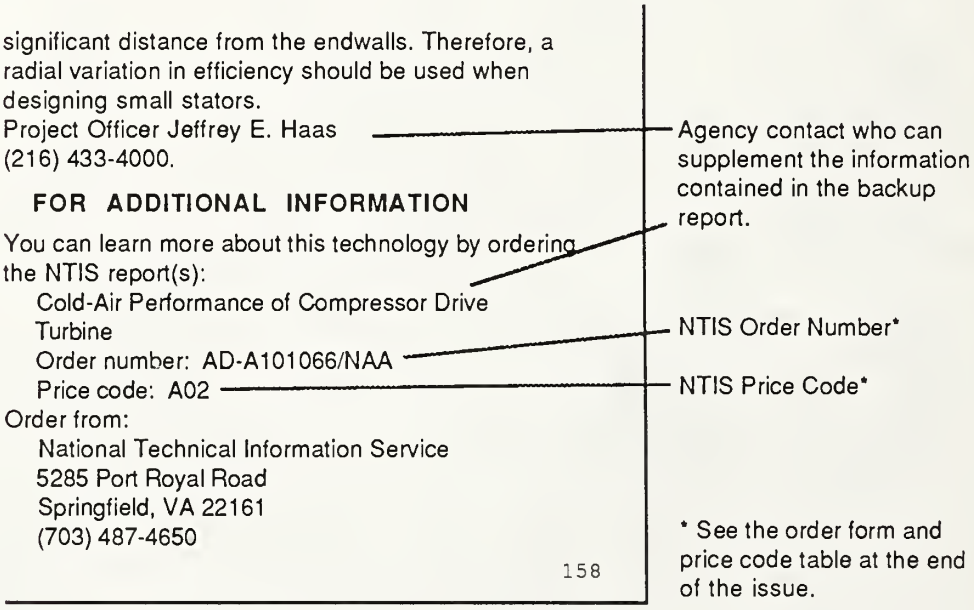
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Project Officer Jeffrey E. Haas
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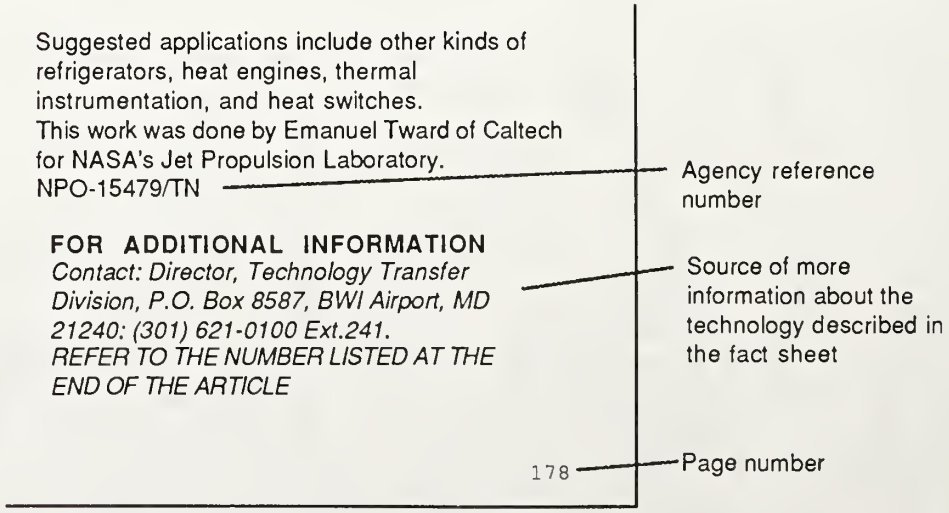
Suggested applications include other kinds of refrigerators, heat engines, thermal instrumentation, and heat switches.
This work was done by Emanuel Tward of Caltech for NASA's Jet Propulsion Laboratory.
NPO-15479/TN
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Contact: Director, Technology Transfer Division, P.O. Box 8587, BWI Airport, MD 21240: (301) 621-0100 Ext.241.
REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE
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0179 Optical Tool Characterizes Electronic Materials

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Agriculture & Food

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Research Technology
Argicultural Research Service
U.S. Department of Agriculture

Bathing Technique Frees Pollen Cell's Contents

Bathing plump pollen cells in a salt solution, or placing them on slabs of gelatin, may be the fastest way to gently release the cell's contents intact. Those innards, known as pollen protoplasts, might speed up laboratory development of superior plants.

Routinely, powerful enzymes are used in the laboratory to eat away the tough wall of leaf, stem, or root cells, freeing the protoplasts. But these enzymes often damage protoplasts, says plant physiologist Merle L. Weaver.

The protective cell wall can also be painstakingly cut away with a very sharp knife, under a microscope, but only a few protoplasts can be retrieved this way.

The simple and potentially less harmful approach Weaver developed, using pollen from green beans, starts with exposing microscopic pollen cells to a few drops of a dilute salt solution. A natural process—osmosis—takes over, sending water molecules from the saline solution through the cell wall into the protoplast.

The protoplast swells, pressure builds up, and within 5 minutes, it's all over: The protoplast and a thin membrane encasing it pop out through one of the natural pores in the cell's wall, to float away, like a tiny balloon, from the now empty cell.

In some ways, this saline technique mimics nature. When pollen lands on a flower, the pollen cells quickly absorb water. Pressure builds up inside the protoplast, causing one or more pores in the cell wall to rupture. But instead of forming a "balloon," the protoplast gradually emerges as a narrow pollen tube. It grows down through the flower to fertilize egg cells in the ovary.

Another gentle way to remove the pollen cell wall of some plant species is to place the cells on solid gelatin. Cell walls shatter in 2 to 8 hours, says Weaver, who has used gelatin to strip walls from pollen cells of green peppers, tomatoes, lima beans, cucumbers, zucchini, soybeans, and black-eyed peas.

Although he hasn't tried to produce a healthy plantlet from pollen protoplasts extracted with either saline solution or gelatin, Weaver says there's no indication they couldn't yield normal offspring.

Any plantlet nurtured from a pollen protoplast would contain chromosomes and genes only from the male parent: that means the little plant's genetic makeup is much less complicated than that of a typical seedling with the normal complement of chromosomes and genes from both parents—male and female. A simpler genetic makeup makes it faster and easier for breeders to screen plantlets and zero in on the most-wanted, genetically controlled traits.

Genetic engineers may want to use the technique to take the walls off pollen protoplasts, so they could insert useful genes borrowed from other plants, or perhaps even from other forms of life, such as from beneficial bacteria.

Pollen protoplasts extracted the gentle way might also be used in protoplast fusion. That technique makes it possible to produce new hybrids by fusing

protoplasts of formerly incompatible species—ones that couldn't otherwise be crossed with each other in nature.

For technical information contact Merle L. Weaver, USDA-ARS Western Regional Research Center, 800 Buchanan Street, Albany, CA 94710 (415) 559-5760. *Patent Application Serial No. 07,059,988, "Method to Obtain Intact, Viable Protoplasts from Pollen Grains."*

For Additional Information:

Inquiries concerning rights for commercial use of this invention should be addressed to

Office of Federal Patent Licensing
Center for the Utilization of Federal Technology
Room 304, NTIS
Springfield, VA 22161
(703) 487-4738

Refer to Patent Application 07/059,988/TN

Gene Transport Vehicles Found In Yeasts

Possible new vehicles for moving genes from one microorganism to another have been discovered in four strains of yeasts by an Agricultural Research Service scientist. These genetic molecules—strings of DNA called linear plasmids—may become biotech workhorses along with genetic molecules in bacteria to expand the roles of yeasts well beyond the ancient arts of making bread, alcohol, and fermented foods.

Research on linear plasmids is being done at ARS' Northern Regional Research Center in Peoria, Illinois. Agricultural Research Service geneticist Paul L. Bolen, who discovered the plasmids, is working under a cooperative agreement with the Biotechnology Research and Development Corporation of Peoria.

Until Bolen's discoveries, linear plasmids had been found in only one other yeast. None of the four yeasts he found them in is among the few used commercially today, but that may change, he says.

For example, one yeast found on grapes contains linear plasmids that might someday be used in making citric acid for soft drinks or amylase enzymes for breaking down cornstarch for fermentation.

In the past, commercial interest in expanding the use of yeasts may have been held back by limited knowledge of their biochemistry, says Bolen. "Now that we're gaining an understanding of the uniqueness and diversity of metabolic processes among species, we're beginning to envision a way of creating marketable products inexpensively through fermentation, using genetically engineered yeasts."

Linear plasmids, he says, may even work better than the plasmids that genetic engineers now typically use to shuttle genes between microorganisms.

"Those plasmids are typically circular," says the scientist. "But the linear plasmids in yeast may prove to be better shuttles—in part because they reproduce and float freely within the yeast cell's inner space, or cytoplasm."

BOB BJORK

Geneticist Paul Bolen analyzes yeast DNA in studies that led to his discovery of linear plasmids in the genetic code of four yeasts. These plasmids show potential as vehicles to transport genes from one microorganism to another.

In contrast, he pointed out, circular plasmids, and even linear plasmids that have been found in filamentous fungi, corn, and other higher plants, are surrounded by membranes of cell structures such as mitochondria or the nuclei.

"These membranes are obstacles to getting DNA in or out of a cell," says Bolen.

Bolen and his colleagues have identified linear plasmids in three strains of *Saccharomycopsis crataegensis*—the grape-dweller—and in one strain of *Pichia inositovora.*

In 1981, Bolen says, Japanese scientists found the first linear plasmids in yeast. The yeast, *Kluyveromyces lactis*, ferments milk sugar (lactose) into lactic acid, which is used in many foods and in pharmaceuticals.

And in 1986, British scientists used parts of that same yeast's linear plasmids to make circular ones. Then they got the circular plasmids to reproduce in both that yeast and *Saccharomyces cerevisiae*, the major yeast used in making beer and bread.

Those experiments demonstrated that pieces of linear plasmids can make circular plasmids replicate and in this instance, can be used to shuttle genes between two yeasts. Bolen is conducting similar studies to see if the newly discovered plasmids have that kind of replication ability. If so, the range of commercially usable yeasts and other microorganisms could be broadened, he says.

Bolen and his colleagues discovered the linear plasmids by screening hundreds of yeast strains from more than 14,000 maintained at the Peoria research center.

"From what we've observed so far, linear plasmids may even turn out to be more prevalent than circular plasmids," he says. "All the newly discovered plasmids were linear. We found circular ones only in species where we already knew they existed."-

Paul L. Bolen is in USDA-ARS Fermentation Biochemistry Research, Northern Research Center, Peoria, IL 61604 (309) 685-4011, ext. 272. ♦

United States Department of Agriculture

Research Technology
Agricultural Research Service

Computerized Apple Records Bumps

Apple abusers, be forewarned. A computerized "apple" may tattle on hard knocks that can damage fruit.

Just 3-1/2 inches in diameter, the battery-powered gizmo is an ingenious assembly of electronic parts cast in a sphere of beeswax. "It's small enough to be packed in containers with real apples," says Galen K. Brown, a U.S. Department of Agriculture engineer.

"The artificial apple automatically records the bumps that real apples receive as they're moved from orchards to retail stores," says Brown, who is with USDA's Agricultural Research Service in East Lansing, Michigan.

Apple losses after harvest—caused by damage from handling, shipping, and storing—total millions of dollars annually. Because fresh apples command higher prices than processed apples, growers prefer to minimize damage rather than sell their fruit for applesauce.

Brown adds that the invention could be scaled up or down and reshaped to study damage to citrus, melons, peaches, tomatoes, potatoes, and cucumbers.

Inside the apple is an accelerometer to measure the force and duration of bumps. A clock records the precise time when each bump occurs.

These data are memorized and later fed into a personal computer that is set to notice only those bumps hard enough to cause damage. Later, researchers can compare the history of impacts revealed in the printout with actual bruises on the fruit.

The computerized apple is the product of cooperative research between a team of ARS and Michigan State University engineers.

Since last fall, the apple has been tested in several packing lines. It consistently helped researchers pinpoint locations in the handling system where damage occurs and recommend improvements in equipment and handling procedures to reduce apple damage.

BOB BJORK

Packed alongside fruit, this electronic imposter helps evaluate handling procedures from packinghouse to market.

Last November, the apple was packed in containers with real apples and field-tested in trucks on trips of 30 to 360 miles.

On truck runs, the least damaged apples were held in a cell pack, a plastic foam pack encasing each apple in an individual cell. "Regardless of mileage, a short section of rough highway can take its toll on even carefully packed apples," Brown says.

By adding other sensors to the apple, temperature and humidity data could also be recorded to help evaluate conditions during storage and transport.—

Galen K. Brown is in USDA-ARS Fruit and Vegetable Harvesting Research, Michigan State University, East Lansing, MI 48824 (517) 353-5185. ♦

Computers

0159 FIPS for POSIX Approved

0160 Small Computers Linked to Give Supercomputer Capability

Software

0161 Asynchronous Communication Scheme for Hypercube Computer—Average delays are reduced. (Licensing Opportunity)

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NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

FIPS For POSIX Approved

A Federal Information Processing Standard (FIPS) for POSIX--a portable operating system interface--is now in effect as the first step toward a more open software environment for federal agencies. It adopts a draft standard developed by the Institute of Electrical and Electronics Engineers in conjunctionwith NIST and industry. The new standard will enable federal agencies to begin specifiying POSIX in procurements. POSIX defines the interface, or link, between applications and computer operating systems based on UNIX, originally developed by AT&T. With the assistance of guest scientists from AT&T and Digital Equipment Corp., NIST has developed test methods needed by industry and users to ensure that operating systems conform to the new FIPS. The conformance test suite is now available from the National Technical Information Service. In addition, NIST is sponsoring a series of workshops to allow industry and government to discuss ways to update and extend the current standard to allow more functions for users.

FOR ADDITIONAL INFORMATION: For information on the workshops, contact James A. Hall, telephone: 301/975-3273. Order Federal Information Processing Standard (FIPS) 151, POSIX: Portable Operating System Interface for Computer Environments, from the National Technical Information Service, Springfield, VA 22161.

Sandia National Laboratory

Small Computers Linked To Give Supercomputer Capability

Scientists at Sandia National Laboratories in Livermore, Calif., have developed a supercomputer capability from their existing network of small computers. Using 14 VAX computers on the network, which spans 1,100 miles, Sandia scientists demonstrated Cray-like performance on major applications problems. This capability, known as "SUPERNET," allows small computers to augment Sandia's overburdened Cray supercomputers.

The computers in the network are run using "parallel processing" techniques in which each computer is assigned only a part of the overall computation. The project began as a joint research venture involving Sandia, Scientific Computing Associates, Inc., (SCA), and Yale University to use a software system known as Linda in an engineering application.

The Linda software system, developed by Yale computer science researchers David Gelernter, Nicholas Carriero, and Jerrold Leichter, represents a high-level approach to parallel processing. It enables scientists and engineers to develop applications for parallel computers without concern for the underlying computer architecture. The engineer can concentrate on designing while Linda coordinates the various parts of the computation.

"SUPERNET" is an excellent example of the type of achievement that is possible through the collaborative efforts of American universities, industry, and government," says Robert Whiteside, program manager at Sandia.

Leichter, who developed the VAX version of the Linda software, worked with Whiteside to install the system at Sandia. Whiteside then used Linda to run a rocket plume simulation analysis with a SUPERNET configuration consisting of 14 computers: three VAX processors at Sandia Livermore and 11 VAX processors distributed in various buildings at Sandia's facility in Albuquerque. (VAX computers, made by Digital Equipment Corporation, are in widespread use for general scientific computing at Sandia and elsewhere.) The analysis ran in 143 minutes on the SUPERNET, twice as fast as on Sandia's Cray 1 supercomputer.

Whiteside also converted a semiconductor device problem from the Cray supercomputer to an eleven-VAX SUPERNET configuration. This problem ran in 74 minutes on the Cray. The same calculation took 151 minutes on SUPERNET, which represents a significant price/performance achievement.

An additional engineering code, a thermal analysis program, was converted to SUPERNET. The timing results for this program demonstrated that SUPERNET is inefficient for some computations, achieving only 6 percent of the Cray performance. The inefficiency results from the large communication overhead incurred by the various processors exchanging data among one another during the run.

As the rocket plume analysis demonstrates, for some engineering applications SUPERNET will outperform the Cray. Nevertheless, the basic goal is not to try to exceed supercomputing performance but to achieve supercomputer capability by fully utilizing existing minicomputers. The system allows a large research and development laboratory like Sandia to make round-the-clock use of its existing computers, linking them in parallel and using them in parallel, to solve very large and complex scientific problems.

The Linda software easily enables the VAX computers to run in parallel. William Wilson, manager of computation at Sandia Livermore, says that with Linda the existing computer codes have to be converted to parallel processing formats only once. They don't have to be redone for every new configuration of computers. "Once the codes are parallelized," he says, "Linda does all the rest."

Joe Harris, supervisor of applied mathematics at Sandia Livermore, says, "The performance results of the thermal analysis program demonstrate the limitations of this type of parallel processing. Many applications will run poorly on the network. Obviously, SUPERNET is not a replacement for traditional supercomputers."

However, for applications that can use SUPERNET, this represents a substantial increase in capacity. Says Wilson, "This development could save the nation literally hundreds of millions of dollars in additional computer capacity.

FOR ADDITIONAL INFORMATION

Public Information Division,
Code 3161,
Department of Energy,
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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Asynchronous Communication Scheme for Hypercube Computer

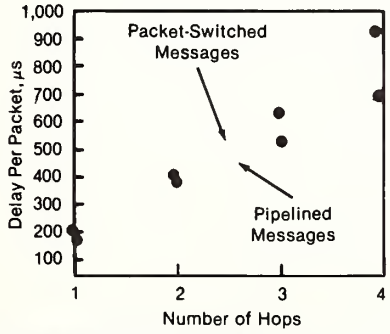
Average delays are reduced.

A generalized scheme has been devised for an asynchronous-message communication system for the Mark III hypercube concurrent-processor network. The scheme is intended to support applications that require the passage of both polled or solicited and unsolicited messages.

The network may consist of up to 1,024 processing elements connected electrically as though they were at the corners of a 10-dimensional cube. Each node contains two Motorola 68020 processors along with the Motorola 68881 floating-point processor utilizing up to 4 megabytes of shared dynamic random-access memory.

The primary goal in designing the software for the communication system is to take advantage of the highly parallel architecture of each node, allowing the main processor to proceed with computations while the input or output is in progress. Secondary goals include offering both packet switching (for single-packet messages) and virtual-circuit switching (pipelining of paths for multipacket messages), along with the ability to expand and reconfigure to support various applications specified by the user.

The scheme includes a regular-message-transfer and a fast-message-transfer mode for communication between nodes. It also addresses such issues as control of the flow of messages, routing, buffering, detection and correction of collisions, and the control of congestion to prevent deadlock.



The **Average End-to-End Delay** per packet increases with the number of hops. This plot was obtained by simulations of the transmission of multipacket messages with an average size of 512 bytes.

In the regular transfer mode (for single-packet messages), a single-packet message is transferred from the shared memory to the local transmitting buffer in the communication processor and is subsequently transmitted in the regular packet-switched mode to its eventual destination along one of the available paths. This path is determined by reference to the message-routing table to locate an available outbound channel.

Each intermediate node that receives the single-packet message either forwards the packet along the forward path if any one of the alternate channels is available or else returns (backtracks) the packet to the last forwarding node that sent this packet. The last forwarding node then reroutes the packet along a different path.

In the fast-message-transfer mode (to be used for multipacket messages), the communication processor starts the process of setting up a path (virtual circuit) to the destination node by using the message-routing table to determine the outbound channels. The technique of setting up a path prior to the transfer of data is called the prior-notification-of-intended-message-transfer/path-validation process and is particularly useful for long messages. Each of the successive intermediate nodes then establishes the path by pipelining the inbound channel-number specification to the outbound channel-number specification by use of a path-setup/reference table in the local memory of each node. At each node, a reverse path is also set up simultaneously for an end-to-end acknowledgment from the destination node.

The destination node attempts to allocate the requisite memory, then responds with an acknowledgment/error packet back to the source along the reverse path. Next, the forward path is confirmed at all intermediate nodes, and the source node is notified to transmit the multipacket message. Meanwhile, the reverse path is deallocated at all the intermediate nodes soon after the acknowledgment. All intermediate nodes en route to a given destination simply perform a direct-memory-access transfer of data, thus speeding up the data-transfer process by an order of magnitude. The pipelined path in each path-setup/reference table is destroyed when the requisite numbers of bytes have been transferred.

The effects of the communication on an 8-node and on a 16-node hypercube processor were examined in simulations performed on a VAX 11/780 computer. Among other things, the simulation showed that the average delay per packet is less for pipelined messages than it is for packet-switched messages (see figure). The optimal message size for which pipelining reduces the overhead below that of pure packet switching is in excess of 256 bytes.

This work was done by Herb S. Madan of Caltech for **NASA's Jet Propulsion Laboratory.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL
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Definition of Touch-Sensitive Zones for Graphical Displays

Touch zones are defined simply by touching, while editing is done automatically.

The development of a touch-screen interactive computing system can be a tedious task. The Interactive Editor for Definition of Touch-Sensitive Zones computer program greatly increases the efficiency of human/machine communications by enabling the user to define each zone interactively, thus minimizing redundancy in programming and eliminating the need for manual computation of the boundaries of touch areas. The information produced during the editing process is written to a data file, to which access can be gained easily when needed by an application program.

The touch-editing program is linked as a subroutine to the display-generating software. After answering questions concerning the format of the desired data file, the user defines each area individually by touch. The user touches the screen in one corner of the desired zone and then moves to the opposite corner of the zone without breaking contact with the screen. As this is done, a rectangle is drawn on the monitor showing the user the touch zone as it is being defined. The rectangular area expands dynamically with the motion of the user's finger, as though the periphery were being stretched like a rubberband. When the area is defined to the user's satisfaction, the coordinate data are written to the file.

Additionally, diagnostic routines in the editing program alert the user when touch areas overlap and allow for correction of the error. The application program can then provide the appropriate response to a touch input by using the data file to determine easily which, if any, area has been pressed.

This program has been implemented in VAX-11 FORTRAN on a DEC VAX 11/780 computer operating under VMS 4.4. Graphics routines are written in the Real-Time Animation Package (RAP), a high-level graphics language used to control the Adage, Inc., Adage-3000 programmable display generator. Any VAX that controls a graphic display by communicating with a RAP procedure can use the editing program in its present implementation. The program has a memory requirement of under 10,000 8-bit bytes and was released in 1988.

This program was written by Burt L. Monroe III and Denise R. Jones of **Langley Research Center**.
LAR-13822/TN

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Permanent-File-Validation Utility Computer Program

Errors in files can be detected and corrected during operation.

The Permanent File Validation (PFVAL) utility computer program provides CDC CYBER NOS sites with a mechanism to verify the integrity of the permanent file base. PFVAL locates and identifies permanent file errors in the Mass Storage Table (MST) and Track Reservation Table (TRT), in the permanent file catalog entries (PFC's), in the permit sectors, and in the disk sector linkage. All detected errors are written to a listing file and to the system and job day files.

A site can use PFVAL either to verify that the permanent file base is intact or to isolate errors for correction via the Display Disk File (DDF) utility computer program, a CDC NOS standard product. The program can also be used to clear an error idle condition on a disk (entry point CLREI) and to perform online validation of the track linkage in the MST/TRT for a specified mass storage device (MSVAL).

The program operates by reading system tables (the MST and TRT), the catalog track (PFC's), the permit sectors, and the disk linkage bytes to validate expected and actual file linkages. This program has been used extensively to identify and locate errors in permanent files and enable online correction, thus reducing computer-system downtime.

PFVAL is written entirely in COMPASS (CPU & PPU) and includes common decks and has been implemented on a CDC CYBER 170 and 180 series running NOS version 2. Approximately 22,000 words (octal) are initially required for execution, but field length will increase as internal tables are built. The program was developed in 1983.

This program was written by Stephen D. Derry of Unisys Corp. for **Langley Research Center**.
LAR-13946/TN

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Production of Viewgraphs With TEX

Typesetting functions are grouped conveniently.

TEXVIEW is a software package of TEX macros that facilitate the production of viewgraphs. TEXVIEW is based on TEX, a public-domain typesetting language developed by Dr. Donald Knuth of Stanford University. The TEXVIEW macros are grouped into the following categories: format control, indentation control, font control, spacing control, graphical control, and page layout.

TEXVIEW is written in TEX. Optional command procedures and command definition files for producing a high-speed version when run under VAX/VMS are included. Although implemented on a VAX under VMS 4.X, TEXVIEW is independent of the computer and output device. The program was developed in 1987.

This program was written by Peter J. Scott of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 60 on the TSP Request Card.*
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Electrotechnology

0165 Acquisition Technique for Spread-Spectrum Codes—The ability to lock onto a signal is increased with minimal equipment.

0166 Antireflection/Passivation Step for Silicon Cells—A new process excludes the usual silicon oxide passivation. (Licensing Opportunity)

0167 Circular-Waveguide Power Combiner/Divider—A large number of inputs or outputs can be accommodated.

0168 Contactless Coupling for Power and Data—The alignment of this flat-plate interface is not critical.

0169 Forming n/p Junctions with an Excimer Laser—Compact equipment yields high-quality solar cells. (Licensing Opportunity)

0170 Force-Balance Dynamic Display—Six dynamic signals are simultaneously monitored on a single-trace oscilloscope. (Licensing Opportunity)

0171 Integrated Inverter and Battery Charger—A dual-function circuit would obviate duplication of electrical components and structural parts. (Licensing Opportunity)

0172 Liquid-Crystal-Television Image Subtracters—Image data are processed quickly by optical components. (Licensing Opportunity)

0173 Making EDM Electrodes by Stereolithography—Electrodes with complicated shapes are made quickly from computer models.

0174 Phase-Length Optical Phase-Locked-Loop Sensor—This system provides high resolution without loss of dynamic range.

0175 Simulating Line-of-Sight Radar Returns—Invisible terrain features are removed from further consideration.

0176 Switching Voltage Regulator—Both pulsed and continuous outputs are available.

Testing & Instrumentation

0177 Mounting Thin Samples for Electrical Measurements—A vacuum chuck holds samples gently but securely.

0178 Isolated Data Acquisition in Hostile Environments

0179 Optical Tool Characterizes Electronic Materials

0180 NIST Expands Capabilities of Anechoic Chamber

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Acquisition Technique for Spread-Spectrum Codes

The ability to lock onto a signal is increased with minimal equipment.

A technique has been proposed to improve the acquisition of a spread-spectrum (pseudonoise) coded signal modulated by a digital data signal. In essence, the technique is to divide the correlation time into subintervals, integrate over the subintervals, pass the integrator outputs through square-law detectors, and add the detector outputs over all the subintervals to reach a decision regarding detection of the code. This reduces the effect of data-bit transitions at the price of non-coherent-combining loss.

Accurate and fast synchronization plays a cardinal role in the efficient utilization of any spread-spectrum system. Typically, the first step in the process of synchronization between the spreading (incoming) pseudonoise code and the local despreading (receiver) code is the acquisition of the code. It is a process of successive decisions wherein the ultimate goal is to bring the two codes into coarse synchronization within one code-chip interval.

Another major issue is the degree of parallelism in the acquisition scheme. At one extreme, one steps through the uncertain-code-phase region in a serial manner. A detection threshold is selected to perform compromises among the probabilities of detection, missing and false alarms, and the mean acquisition time. At the other extreme is the totally parallel acquisition scheme, in which the correlation for every uncertain code-phase offset is performed simultaneously. The outputs are compared, and the one having the largest value is selected. The comparison between the two extremes involves the speed of acquisition versus the cost of equipment.

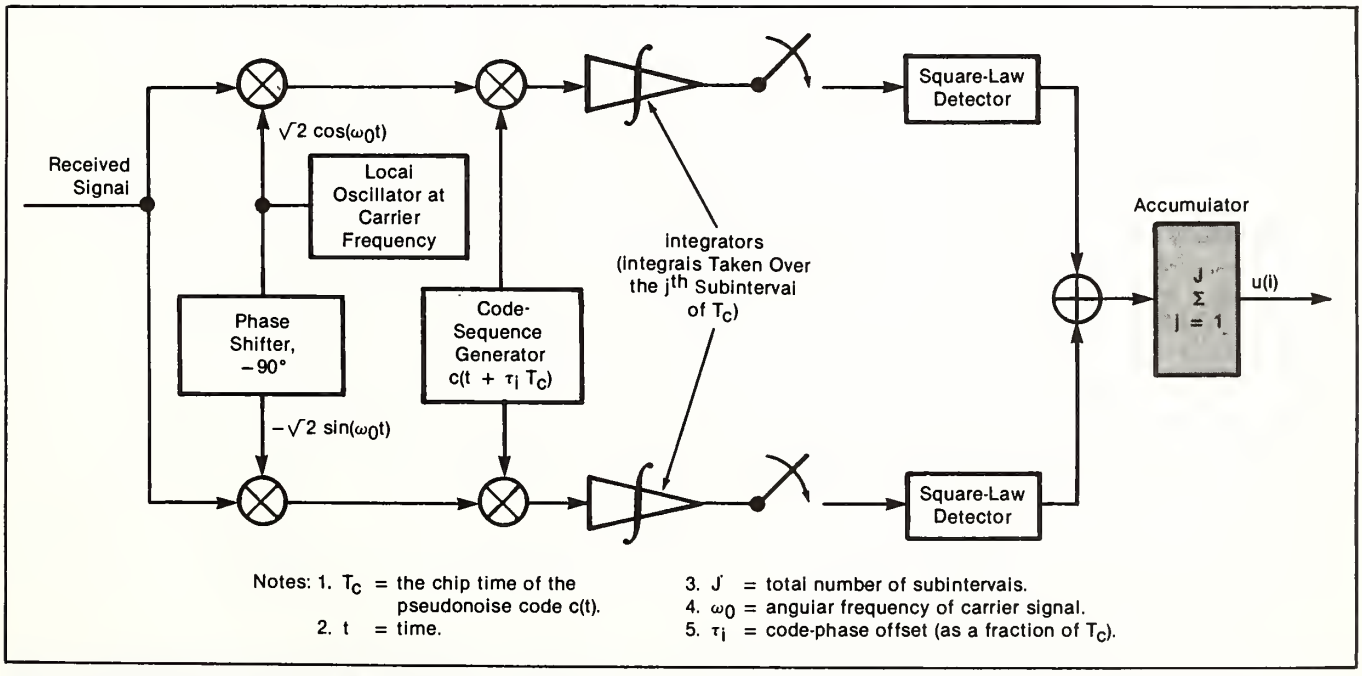
Modifications of these two schemes could result in various hybrid schemes of intermediate speed and cost, including those of the new technique. For instance, one might partition the uncertain-code-phase region into subsets, considering one subset at each step. The outputs for all code-phase offsets in the prevailing subset are compared. The decision that the code has been detected is made if the largest output exceeds a preselected threshold; otherwise, the next subset is examined.

The figure illustrates the overall structure of the new detector system. The code despreading occurs at baseband. The local code generator has code-phase offset (lag) τ_j. In the case of parallel acquisition, there are many such correlators, each with different τ_j. The total correlation time is partitioned into J subintervals. The outputs of the square-law detector in the J subintervals are noncoherently combined for detection.

The performance of this system has been analyzed theoretically for several totally parallel and hybrid schemes. The optimum number of coherent integration subintervals was shown to be a function of the total integration time. The dependence of mean acquisition time on the number of subintervals decreases as the signal-to-noise ratio increases.

This work was done by Unjeng Cheng of Caltech for **NASA's Jet Propulsion Laboratory**.

NPO-17289 /TN


Received Signal
√2 cos(ω0t)
Local Oscillator at Carrier Frequency
Phase Shifter, −90°
−√2 sin(ω0t)
Code-Sequence Generator c(t + τj Tc)
Integrators (Integrals Taken Over the jth Subinterval of Tc)
Square-Law Detector
Square-Law Detector
Accumulator
J Σ j = 1
u(i)
Notes: 1. Tc = the chip time of the pseudonoise code c(t).
2. t = time.
3. J = total number of subintervals.
4. ω0 = angular frequency of carrier signal.
5. τj = code-phase offset (as a fraction of Tc).

The Partially Noncoherent Correlator/Detector implements a hybrid scheme for the acquisition of a pseudonoise code in the presence of data modulation.

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NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

NASA's Jet Propulsion Laboratory, Pasadena, California

Antireflection/-Passivation Step for Silicon Cells

A new process excludes the usual silicon oxide passivation.

An antireflection coating for silicon solar cells also passivates the silicon surface, making an extra passivation step unnecessary during fabrication of cells. The coating consists of a double layer, one of titanium oxides (TiO_x) and the other of Al_2O_3.

The TiO_x and Al_2O_3 are deposited on the cell after the junction has been formed and the contacts have been metalized. The layers are formed by evaporating titanium and aluminum in an oxygen-rich atmosphere. During evaporation, the cell is heated to 75 °C. Afterward, it is annealed in pure hydrogen at 350 to 400 °C for 5 to 10 minutes.

While increasing cell output by reducing light lost by reflection from the surface, the coating is as effective in passivating the cell as is the usual, thermally grown layer of silicon oxides (SiO_x). It reduces the reverse saturation current and thereby increases the open-circuit voltage and efficiency of the cell to almost the same extent as SiO_x. It does so without the disadvantages of the SiO_x passivation: processing temperatures above 450 °C that can degrade performance; questionable stability, quality, and reproducibility; incompatibility with some antireflection coating materials; and the cost of an extra step.

In an experiment, a cell fabricated with SiO_x passivation was compared with a cell fabricated without SiO_x passivation. The increase in open-circuit voltage, short-circuit current, and energy-conversion efficiency due to the antireflection treatment alone was only slightly less than that due to the combination of antireflection and SiO_x-passivation treatments (see table).

Treatment	Cell Number	Open-Circuit Potential, mV	Short-Circuit Current, mA	Efficiency, Percent
None	1	608	90.4	10.94
Oxide Passivation	2	633	90.9	11.49
Antireflection	1	641	132.9	17.19
Antireflection After Passivation	2	643	130.4	17.13

The Changes in Principal Electrical Parameters during two kinds of processing suggest that the antireflection treatment is almost as effective as the oxide treatment is in passivating the cells.

This work was done by Gerald T. Crotty, Akaram H. Kachare, and Taher Daud of Caltech for **NASA's Jet Propulsion Laboratory.**

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NASA Tech Brief
National Aeronautics and Space Administration
Goddard Space Flight Center, Greenbelt, Maryland

Circular-Waveguide Power Combiner/Divider

A large number of inputs or outputs can be accommodated.

Because solid-state sources have limited power output at millimeter wavelengths, it is often necessary to combine the power from many devices to achieve the required transmitter power. Several advantages accrue if the power output is in the TE_{01} mode of circular waveguide rather than of the more-conventional rectangular waveguide. This circular mode has lower loss than that of the rectangular guide and is ideal for the construction of the rotary joints that are often required between the transmitter and antenna. Therefore, a power combiner/divider has been devised in which the output from several solid-state modules can be combined directly into the TE_{01} mode of the circular waveguide.

The principle of operation is most easily explained for the combining mode. An arbitrary number, N (in this case, $N = 16$, but more or fewer could be used), of radio-frequency sources radiate power through N rectangular waveguides, which converge radially and symmetrically until they terminate on the circumference of a circular waveguide (see Figure 1). The electromagnetic fields of the rectangular waveguides are coupled through irises to the electromagnetic field of the circular waveguide.

The rectangular waveguides are oriented with their broad-wall dimensions parallel to the axis of the circular waveguide, so that if the N sources are in phase, they excite the TE_{01} electromagnetic mode in the circular waveguide.

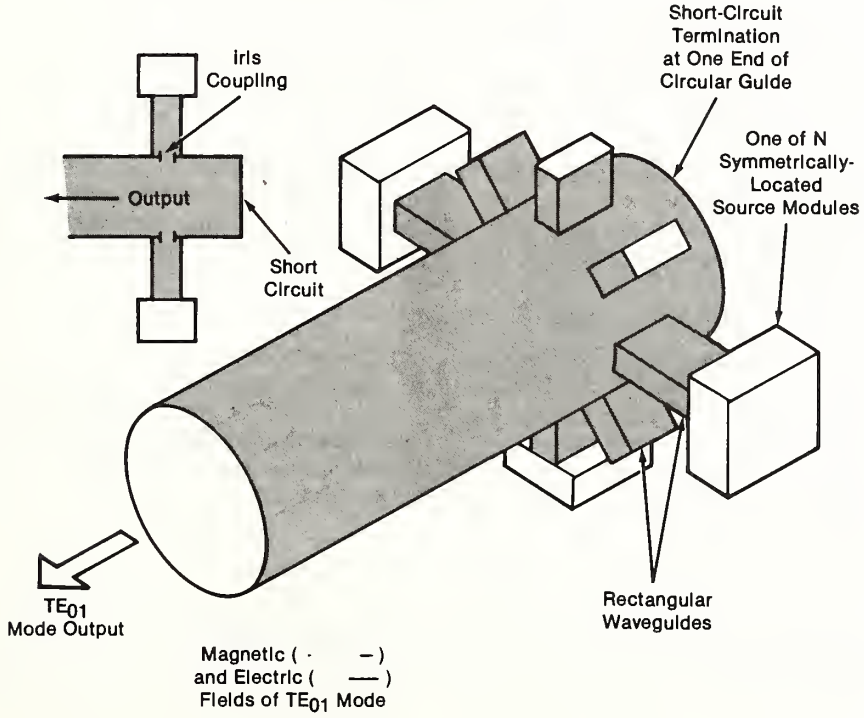
Short-Circuit Termination at One End of Circular Guide
Iris Coupling
One of N Symmetrically-Located Source Modules
Output
Short Circuit
TE01 Mode Output
Rectangular Waveguides
Magnetic (· · · —)
and Electric (— —)
Fields of TE01 Mode

Figure 1. **Electromagnetic Fields** are coupled from N radio-frequency sources to the TE_{01} mode of a circular waveguide.

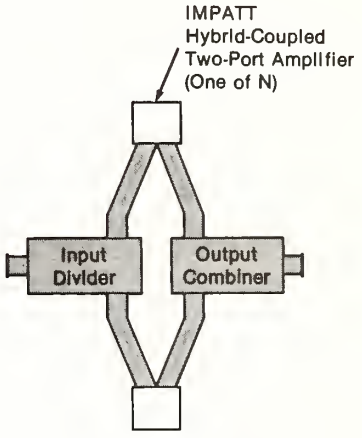

Figure 2. A **Microwave Amplifier Assembly** includes a divider that distributes the input signal to N impact-avalanche-and-transit-time (IMPATT) diode amplifiers and a combiner, which, as the name implies, combines the outputs of the N amplifiers into one output.

Care must be taken to match the impedances at the various junctions. The impedances of the circular waveguide and the converging rectangular waveguides are matched by uniform dielectric chips placed symmetrically near their junctions.

Other combiner/dividers have been inherently narrow-band devices or wide-band devices limited in the number of input ports or have exhibited high losses. In addition to providing the output in the desirable TE_{01} mode, the new combiner/divider concept results in a low-loss, wide band device: Because of the axisymmetry of the TE_{01} mode, there is no essential limit on N. The latter feature is an advantage in the design of wide band, high-power, solid-state amplifiers operating at millimeter wavelengths (see Figure 2).

This work was done by Vernon Dunn of Ford Aerospace and Communications Corp. for **Goddard Space Flight Center**. *No further documentation is available.*
GSC-12996/TN

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NASA Tech Brief
National Aeronautics and Space Administration
Goddard Space Flight Center, Greenbelt, Maryland

Contactless Coupling for Power and Data

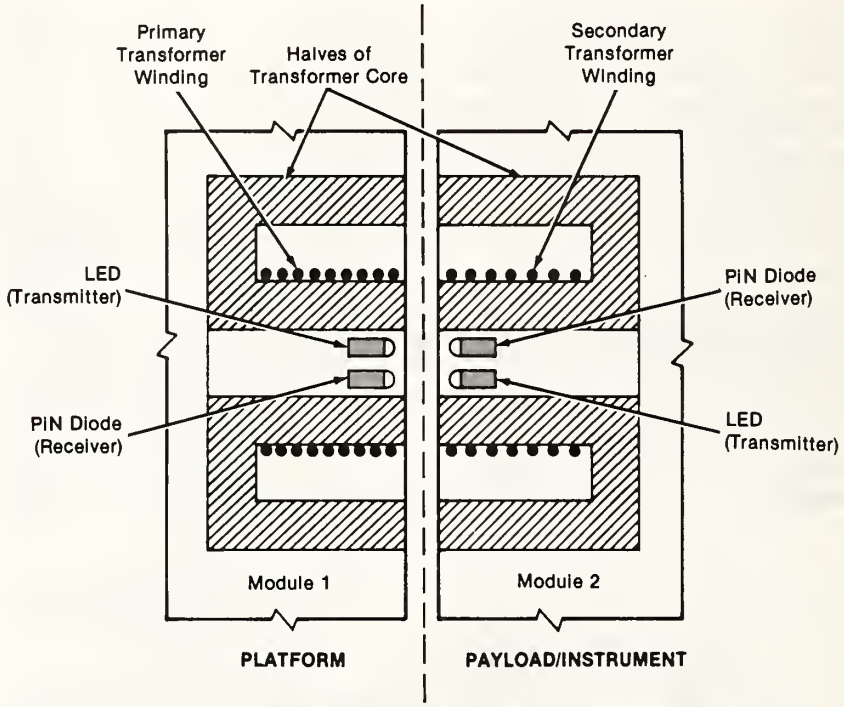
The alignment of this flat-plate interface is not critical.

An experimental flat-plate coupling transmits digital data signals and electrical power across a small gap between two modules. Unlike multiple-pin electrical connectors, the two halves of the coupling do not have to be aligned precisely for mating; thus, the coupling concept may be a useful substitute for electrical connectors in equipment that has to be assembled by robots, remote manipulators, or humans working in protective clothing or otherwise restricted in dexterity.

The coupling includes a power transformer operating at a frequency of 20 kHz. Each of the mating modules contains half of the pot-shaped core of the transformer and a spiral winding (see figure). Two versions have been built: one to transfer 100 W of power, the other to transfer 1,000 W.

The transformer is designed to operate at maximum efficiency with a gap of 10 to 20 mils (0.25 to 0.5 mm) between the halves of the core. This eliminates the need to force the halves into contact and thereby also minimizes wear of the mating surfaces. The 100-W version of the transformer has been tested for its performance with various gaps, lateral displacements, and angular misalignments. Within the tolerance range, the transformer exhibits an efficiency as high as 97 percent.

The data-transmission system includes light-emitting diode (LED) transmitters, positive/intrinsic/negative (PIN) diode receivers, and Motorola (or equivalent) emitter-coupled-logic supporting electronic circuitry. The transmitting and receiving diodes are equipped with lenses that give some divergence to the transmitted light beam and field of view, respectively. Consequently, the digital-signal coupling also has some tolerance to separations and misalignments. The data-transmission system has been tested with a 50-MHz signal representative of a 100-Mb/s nonreturn-to-zero pulse code.



A Split Transformer and Optoelectronic Components transmit electrical power and digital signals, respectively, across a small gap. This coupling would be useful in robotically assembled equipment because it tolerates some misalignment. The coupling offers also higher reliability due to one overall alignment mechanism as opposed to multiple pin/socket alignment requirements.

This work was done by John C. Moody and Joseph W. Foley of OAO Corp. for **Goddard Space Flight Center**. *No further documentation is available.*
GSC-13059 /TN

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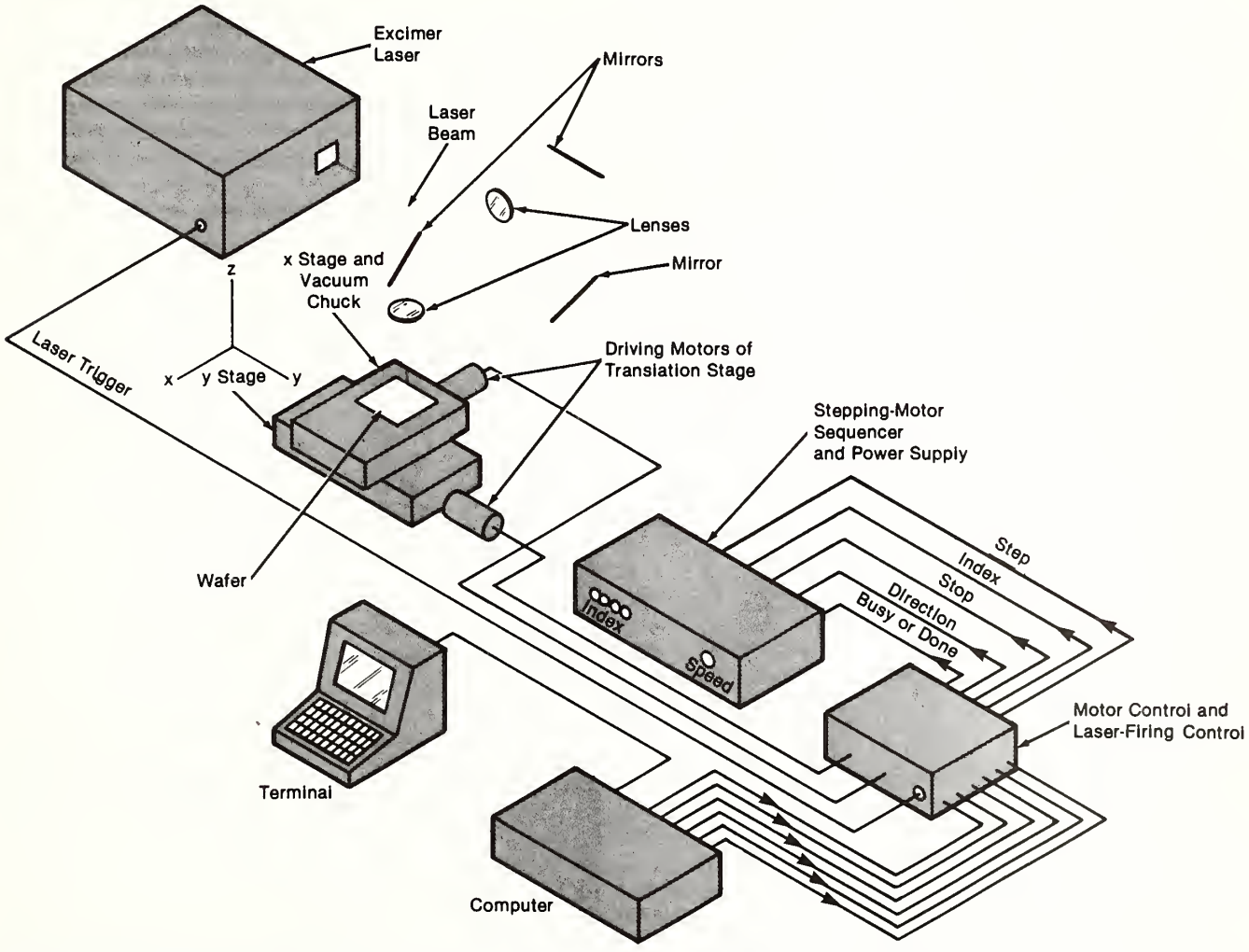
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Forming n/p Junctions With an Excimer Laser

Compact equipment yields high-quality solar cells.



The Computer Controls the Pulses of the excimer laser and the movement of the silicon wafer. The mirrors direct the laser beam to the wafer. The lenses focus the beam to a small spot on the surface.

Heating with the concentrated ultraviolet energy of an excimer laser has proved successful in driving liquid dopants into silicon to form shallow n/p junctions for solar cells. The laser equipment is more compact than the furnaces conventionally used to form junctions by diffusion of vapors. The laser equipment can fit on a tabletop.

In preparation for tests of the laser manufacturing technique, liquid dopants were applied to silicon wafers. The wafers were then heated at 200 to 400 °C for 10 to 15 minutes to drive off solvents; the dopants formed hard, glasslike layers. The wafers were then exposed to the excimer laser. Finally, they were metalized.

The excimer laser is a table model that can be pulsed at rates up to 100 Hz. It produces 20 mJ of energy per pulse at a wavelength of 193 or 308 nm (the higher wavelength was used in the tests).

Mirrors directed the light from the laser to the wafer (see figure). Lenses focused the beam from its original cross-sectional area of 1 cm^2 to 0.01 cm^2 at the wafer. The wafer was held in place by a vacuum chuck on a two-stage motorized *x-y* translation stage. A computer synchronized the motion of the stage with the firing of the laser pulses so that the laser completely scanned the wafer.

The wafers were p-type Czochralski-grown silicon with a <100> crystal orientation, coated on one side with phosphorus-doped liquid to form an n-type layer upon diffusion into the silicon. The wafers were 4 cm^2 in area; the energy density of the laser beam, 1.2 J/cm^2; the duration of the laser

pulses, 25 ns; and the beam path overlapped by 50 percent on each pass.

Under these conditions, the system produced solar cells that had an average efficiency of 9.1 percent without an antireflective coating. This is equivalent to over 13 percent efficiency with an antireflective coating — comparable to that of the best cells made by conventional gaseous diffusion.

The process is also suitable for silicon made by the dendritic-web-growth process. Efficiencies range up to 13 percent with <111> p-type material, 10 cm^2 in area.

This work was done by Paul Alexander, Jr., of Caltech, Robert B. Campbell of Westinghouse Electric Corp., David C. Wong and William L. Bottenberg of Arco Solar, and Stanley Byron of Spectra-Physics, Inc., for **NASA's Jet Propulsion Laboratory**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL
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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Force-Balance Dynamic Display

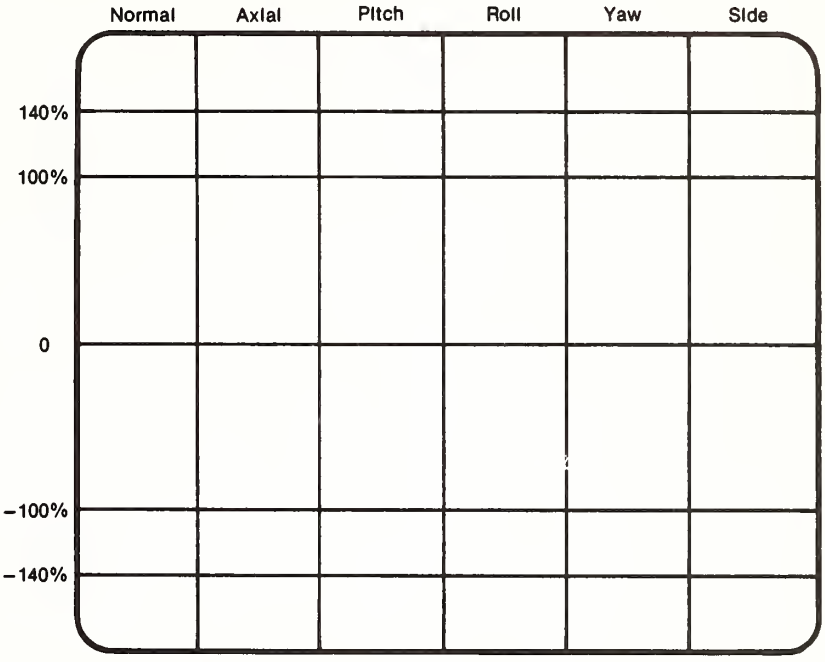
Six dynamic signals are simultaneously monitored on a single-trace oscilloscope.

A balance dynamic display unit (BDDU) is a compact system that conditions six dynamic analog signals so that they can be monitored simultaneously in real time on a single-trace oscilloscope. The instrument was originally designed to monitor the output of a strain-gauge force balance that measures the aerodynamic forces and moments generated about the three orthogonal axes of a model in a wind tunnel. The system features two display modes that are usable with a conventional, single-channel oscilloscope: a multiplexed six-channel "bar-graph" format and a single-channel display. A two-stage visual and audible limit alarm is provided for each channel.

The BDDU accurately monitors, multiplexes, and displays signals in the input range of ±100 mV to ±1 V at frequencies from 0 to 7,000 Hz. Sensitivity and zero-balance adjustments are provided for each channel. For full-scale input, the normalized output is 1 Vdc to both the oscilloscope and the individual buffered outputs. The six normalized buffered outputs provide access for additional recording or analyzing instrumentation.

In the scan mode (see figure), the six multiplexed signals appear as a single trace, on which each channel occupies one-sixth of the total trace width. This mode enables a quick visual overview of the total static and dynamic loads being applied in all axes. In the select mode, a single channel is displayed on the oscilloscope, and the average dc level is displayed on an integral digital panel meter. The BDDU has a thumbwheel switch that enables the selection of any channel for display on the oscilloscope for detailed viewing of any aspect of the signal by use of the normal oscilloscope functions.

Alarms are incorporated into each channel to provide an 8-s visual warning following any pulse of 20 μs or longer duration that exceeds ±100 percent of full scale, and a second visual and audible latching alarm is activated when the input signal of that channel exceeds ±140 percent of full scale for 700 μs or longer. An additional feature has been incorporated into the BDDU to enable the display of the sum and difference of the signals in channels 1 and 3 and of the signals in channels 5 and 6.



A **Typical BDDU Oscilloscope Display** in the scan mode shows each channel occupying one-sixth of the total trace.

This work was done by Alice T. Ferris of **Langley Research Center** *and William C. White of Wyle Laboratories.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center. Refer to LAR-13658/TN

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Integrated Inverter and Battery Charger

A dual-function circuit would obviate duplication of electrical components and structural parts.

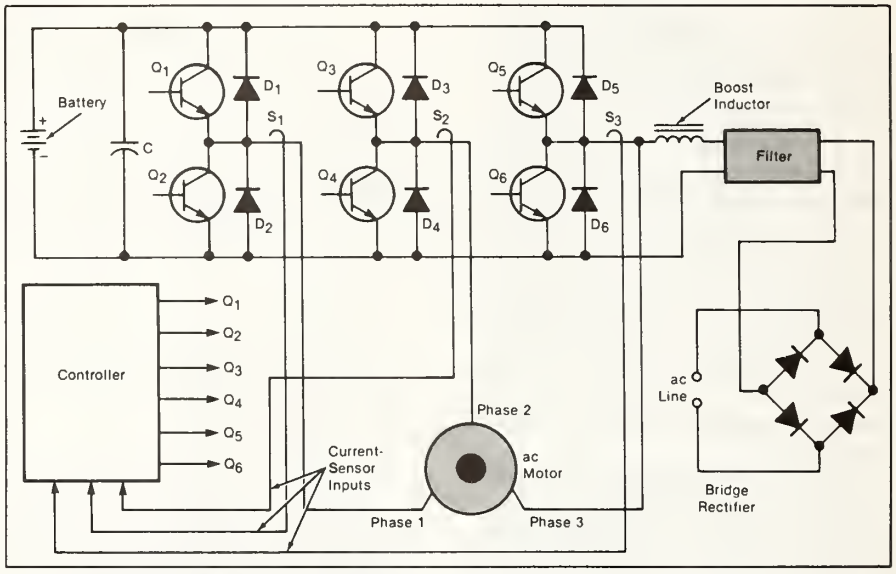
A proposed circuit would combine the functions of dc-to-ac inversion (for driving an ac motor in a battery-powered vehicle) and ac-to-dc conversion (for charging the battery from an ac line when the vehicle is not in use). The circuit would automatically adapt to either mode; there is no need to set switches and relays or disconnect cables.

The design of the integrated inverter/charger would eliminate the need for duplicate components, save space, and reduce the weight and cost of the vehicle. It would offer similar advantages in such other applications as load-leveling systems, standby ac power systems, and uninterruptible power supplies.

The circuit would include a three-phase bridge inverter employing pulse-width modulation, an input capacitor, a line filter, a line rectifier, and control circuitry (see figure). For inverter operation, the controller would switch transistors Q_1 through Q_6 so that voltages and currents of the appropriate magnitude, frequency, and phase would be applied to the motor. Regenerative and reactive currents would be returned to the input capacitor C and the battery by the six antiparallel diodes D_1 through D_6.

The input capacitor would isolate ac components from the battery, acting as a filter that has an impedance to transients lower than that of the battery. The input capacitor would also supply the inverter current pulses to drive the motor, drawing power from the battery on a steady, averaged basis rather than in pulses. Sensors S_1, S_2, and S_3 would measure the currents of the three phases for the controller.

For operation in the charging mode, the controller would modulate the duty cycle of transistors Q_6 to transfer power from the ac line, through the rectifier bridge, the filter, the boost inductor, and diode D_5 to the battery. The controller would act so that the instantaneous line current would be proportional to the instantaneous line voltage; that is, the circuit would operate at a power factor of 1. As in inverter operation, the input capacitor would isolate the battery from transients. The filter would isolate the ac line from the high-frequency components of the modulation pulses. Sensor S_3 would provide a charging-current signal to the controller.



Many Components Do Double Duty in the integrated inverter/charger.

While the battery is being recharged, the controller would keep the other transistors in the off state. Therefore no currents would enter the motor even though a voltage is present at the junction of D_5 and Q_6, because there would be no return paths. The motor would not have to be disconnected during recharging.

The leakage inductance of the motor could be used in place of the boost inductor. The low value of this inductance allows some ripple in the charging current, but the ripple would not be objectionable at the high charging rates that are likely to be used to recharge vehicles quickly. If the ripple were too high for the application, the discrete boost inductor could be retained in the circuit.

Many electrical components could be shared by the inverter and charger portions of the integrated inverter/charger. Other parts that would not have to be duplicated include the battery-connector plug, bus connections, heat sinks, cooling fan, housing, and supporting structure.

This work was done by Wally E. Rippel of Caltech for **NASA's Jet Propulsion Laboratory**.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17133/TN

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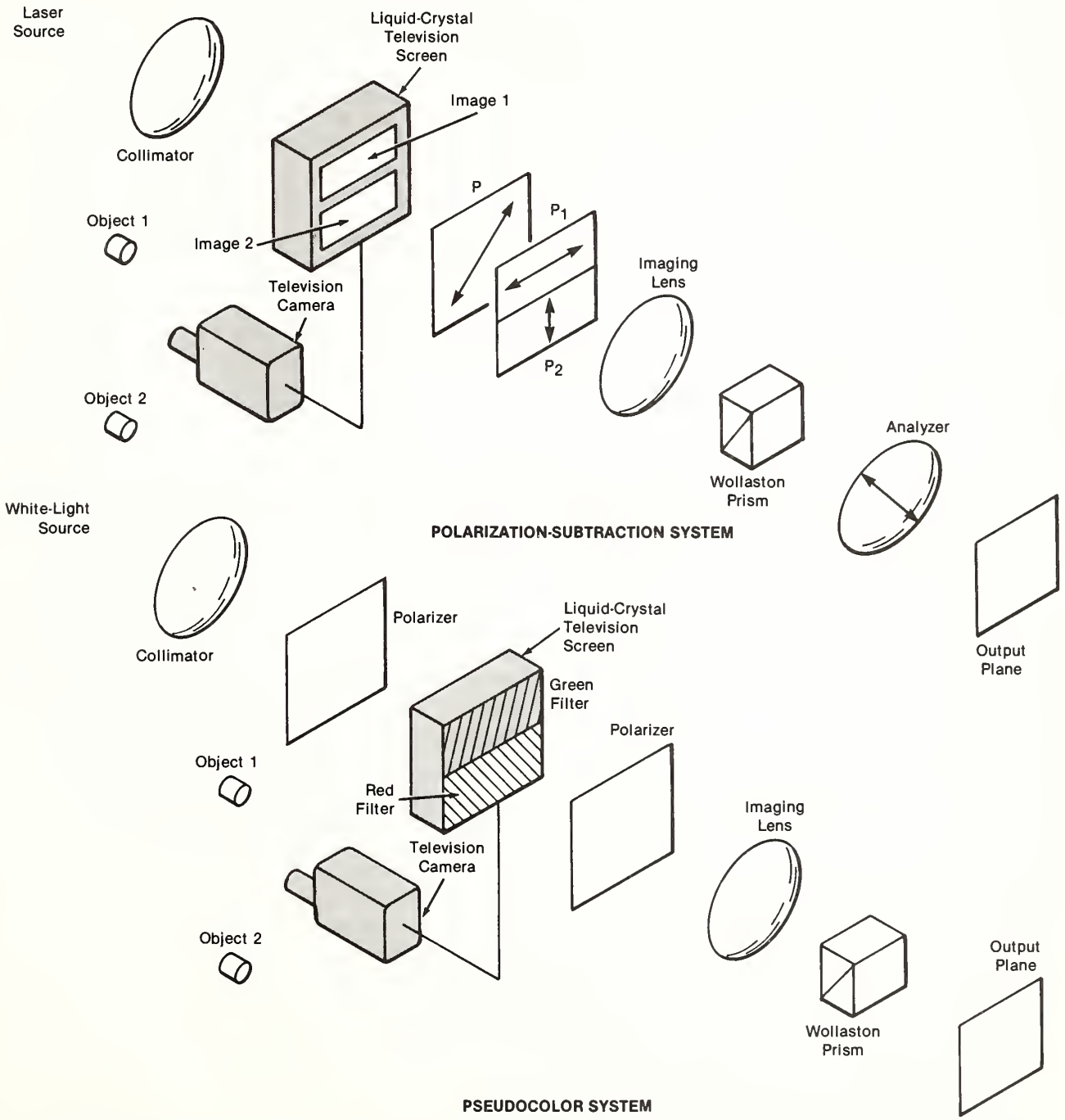
NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Liquid-Crystal-Television Image Subtracters

Image data are processed quickly by optical components.

Either of two similar optoelectronic systems can be used to form an output image that shows the differences between two input images. All parts of the two images are processed simultaneously by optical components only; digital electronic processing



These **Image-Subtraction Systems** form output images that show the differences between the input images of the two objects. In the upper system, the differences appear as bright regions in an otherwise dark output image. In the lower system, the differences and similarities are shown by colors.

of data is not required. Thus, the system concept offers the potential for rapid, inexpensive comparison of images in such applications as automatic inspection, medical diagnosis, and robotic vision.

The first system exploits differences in polarization. As shown in the upper part of the figure, a television camera views the two objects to be compared. The images of the two objects are projected on a liquid-crystal television screen, which is positioned to act as a spatial light modulator. Light from a laser is collimated and passed through the liquid-crystal screen, becoming spatially modulated by the two images as it does so.

The modulated light beam is passed through polarizer P, then through side-by-side polarizers P_1 and P_2. The combination of polarizers is positioned and oriented to make the polarization in one image perpendicular to the polarization in the other. After passing through an imaging lens, the polarized, image-bearing light beam enters a Wollaston prism at a focal plane of the lens. The prism deflects the light according to its polarization; in this case, the prism is oriented to produce equal but opposite deflections of the light from the two images, causing the two images to be superimposed at the output plane of the imaging lens.

On the way to the output plane, the light is passed through analyzer P_3 (that is, another polarizer), which acts in concert with P, P_1, and P_2 to impart opposite polarizations to the light in the two superimposed images. Thus, the identical portions of the two images cancel each other, and only the differences are displayed.

The second system is similar to the first system, except that it is based on pseudocolor encoding. As shown in the lower part of the figure, the liquid-crystal television screen is illuminated through a polarizer with collimated white light. The light modulated with one image is passed through a green filter, and the light containing the other image is passed through a red filter. The light is then processed in a manner similar to that of the first system, except that an analyzer is not used. On the output plane, the superposition of identical red and green portions yields a yellow image. The portions of one image that lie outside the other are shown in red or green.

This work was done by Tien-Hsin Chao and Hua-Kuang Liu of Caltech for **NASA's Jet Propulsion Laboratory**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL
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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

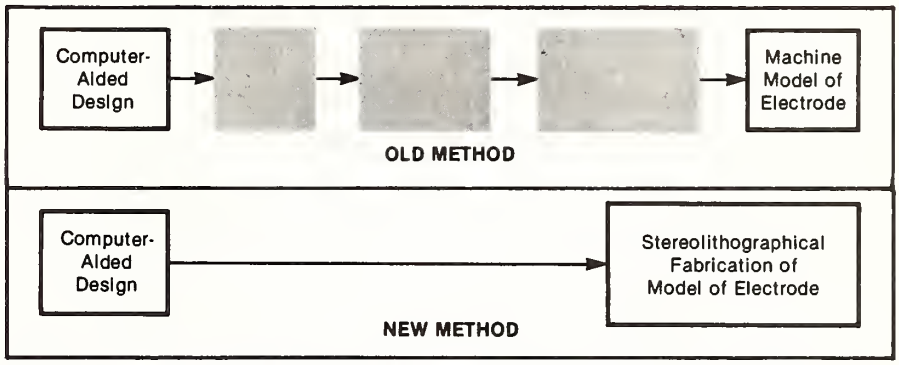
Making EDM Electrodes by Stereolithography

Electrodes with complicated shapes are made quickly from computer models.

Stereolithography can be used to make models and molds of electrodes for electrical-discharge machining (EDM). By use of stereolithography, an engineer can quickly turn the design of an object into a plastic model, bypassing the machining and other intermediate fabrication steps that normally consume much time (see figure). The technique has been proposed for use in making turbopump impellers for the Space Shuttle main engine and can be used to make EDM electrodes for the manufacture of other objects that have complicated shapes.

Stereolithography is a computer-aided manufacturing technique that is practiced in conjunction with computer-aided design and engineering. The three-dimensional computer model of the surface of the object to be made is converted to vector data, which are passed to the data processor of the stereolithography system. This processor uses the data to control an ultraviolet laser, a galvanometer mirror that scans the laser beam in the *x* and *y* (horizontal) directions, and a vertical translation stage in a vat of monomer of a photopolymer below the laser.

The laser beam is focused to a spot in the liquid, causing the monomer to polymerize at that point. The laser beam is scanned across each *x-y* plane; then the vertical translation stage is moved slightly, and the laser beam is scanned across the next *x-y* plane. The process continues, gradually building up the model in layers of accreting polymer. Once the model is thus completely grown, it is hardened in a bath of ultraviolet light.



Stereolithography Eliminates Intermediate Steps in the fabrication of a plastic model of an object to be used in making an EDM electrode to manufacture the object or a mold for the object.

A negative or positive plastic model could be made by this process. A negative model could be used as mold to make positive models, epoxy abrasive dies, or electroformed copper EDM electrodes. It could also be coated with an abrasive and used as an abrasive die to make graphite electrodes. A positive model could be used as a template for tracing by a pantograph or as an injection mold to make EDM electrodes.

This work was done by Philip A. Barlas of Rockwell International Corp. for **Marshall Space Flight Center.** *No further documentation is available.*
MFS-29480/TN

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

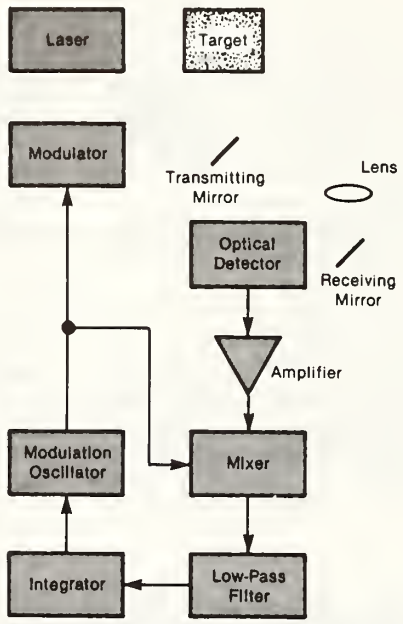
Phase-Length Optical Phase-Locked-Loop Sensor (PLOPS)

This system provides high resolution without loss of dynamic range.

The PLOPS system is designed to provide a high-resolution measurement of the change in optical length from the optical-system source to any optical reflector, including a diffuse reflector. The system has the flexibility to operate from microdimensional to macrodimensional changes. Its use is broad and includes most measurement situations requiring information on length, vibration, and their derivatives. Thus, it can determine distances, structural modal displacements, and vibration frequencies from zero to the high-kilohertz range. Potential applications include building dynamics, remote sensing of vibrations in such systems as turbine-based machinery, monitoring of structural dynamics, noncontacting sensing of surface contours, measurement of large strains as in earthquake monitoring, measurement of atmospheric dynamics and turbulence, high-resolution sensing of humidity, detection of surface acoustic waves by optical microscopy, and related areas.

One version of the optical phase-locked loop (see figure) includes a laser beam as a carrier of an intensity-modulated energy source. The laser beam passes through a modulator to a transmitting mirror. The modulator varies the intensity of the laser beam at a frequency controlled by the modulation oscillator.

The optical beam is directed by the transmitting mirror to a target. Light reflected from the target is focused by a lens, then deflected by a receiving mirror onto an optical detector that converts the intensity signal into an electrical signal. The signal is amplified and enters a mixer, where the sum frequency is removed by a filter, and the difference frequency is used as a measure of the phase of the modulated signal with respect to that of the modulation oscillator.



The PLOPS Serves as an Adjustable Optical Ruler, providing high resolution in the measurements of small and large changes in distance to the target.

The resulting signal is at zero frequency (or dc) and is either a positive voltage or negative voltage, depending on the phase difference between the modulation oscillator and the detected optical signal. At one quadrature point, the voltage will be zero, and the signal integrator will provide a stable operation point for the system by feedback control to the frequency of the modulated oscillator. At that point, the frequency of the modulator sets up an exact number of wavelengths in the optical path.

When the phase-locked loop is locked, the condition of quadrature is maintained so that the phase of the system does not change. Any change in the optical-path length, therefore, changes the modulation frequency. As the target moves, the lock frequency will remain at quadrature, and the change in distance to the target can be monitored from the change in modulation frequency. In addition, the device can be aimed to specific targets, spatially locking onto them with an x,y beam wiggler that operates in a bandwidth different from that of the modulator. Thus the PLOPS can stay locked onto a moving target both spatially and dimensionally.

The PLOPS system has the advantage of high resolution without loss of wide dynamic range. In effect, the choice of the modulation frequency determines the degree of sensitivity of the system. The PLOPS does not depend on coherent reflection from the target and can measure targets that do not have special preparation or corner reflectors. The use of carrier modulation achieves high resolution without the problems of high-speed, short-pulse-duration systems. Thus the PLOPS has the advantage of simplicity, low cost, and small size without sacrificing resolution.

This work was done by Joseph S. Heyman and Robert S. Rogawski of **Langley Research Center.**

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NASA Tech Brief
National Aeronautics and Space Administration
Ames Research Center, Moffett Field, California

Simulating Line-of-Sight Radar Returns

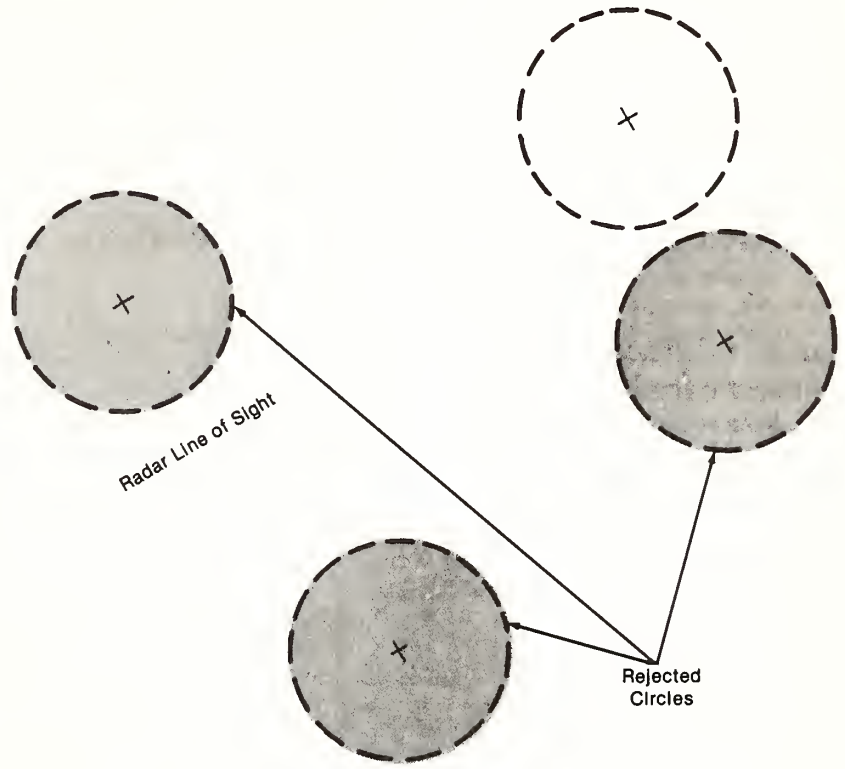
Invisible terrain features are removed from further consideration.

A computational method has been developed to model the return signals of a ground-mapping radar system for use in simulations where the terrain is in a polygonal form commonly used with computer-generated imagery (CGI). The approach involves the fast rejection of polygons not visible to the radar, to speed the simulation of the radar return. The computational technique can be used to determine which objects in a scene are visible from a specified vantage point and might also be used to determine movements of robot arms that avoid obstacles.

A real-time mathematical model of a forward-looking, ground-mapping radar must produce a range-versus-altitude profile of the CGI terrain along the present flightpath vector (FPV) of the aircraft. The profile is that determined by the intersection of the vertical plane containing the propagated FPV with the surface of the CGI terrain, given the simulated position of the aircraft and the coordinates of the vertexes of the CGI polygons. In this case, the radar model is for terrain following only. The guidance computations use the information from only one profile per computation cycle rather than from several profiles per computation cycle, as might be required in terrain avoidance.

The procedure begins with the precomputation of nonvarying parameters (prefight calculations) that are stored prior to the real-time computations. First, all of the labeled vertexes of the CGI system are stored. Next, the beginning and end points of the line segments are defined for the CGI data base. Also required are the angular bearings of all line segments (projection in the x-y plane), as referred to the beginning and end points of the lines.

Major circles (each enclosing three or more mountains) are used for quick elimination of as many CGI mountains as possible from the search. Each major circle is defined by the coordinates of the center, the radius, and the table of the mountains included within it. The selection of how many mountains and which ones to contain in a given major circle is arbitrary and is done by trial and error. A choice of three or four should be sufficient. Major circles should not intersect.



Test Circles are used in an algorithm that quickly rejects terrain features not traversed by the radar line of sight. If a circle does not cross the line of sight, then all the mountains in it are rejected.

A minor circle encloses one mountain with a circle of minimum area. These minimum area circles are found by gradually shrinking and adjusting an enclosing circle until two vertexes touching the circle define a diameter or three vertexes touching the circle form a triangle whose angles are all nonoblique. Under either of these conditions, the circle cannot be shrunk further and still enclose all the vertexes.

Major and minor circles allow the radar line-of-sight intersections with the data base to be determined rapidly by rejecting large portions of the data base with a simple test. If the distance from the line of sight to a major or minor circle is greater than the radius of the circle, then the line of sight cannot intersect anything enclosed in the circle (see figure).

The computational procedure was applied to the simulation of a terrain-following helicopter and required 17 ms to execute on a SIGMA 8 computer. In contrast, a previous method required about 120 ms. It should be possible to decrease the execution time significantly in future simulations.

This work was done by F. J. Moran and J. D. Phillips of **Ames Research Center**. *Further information may be found in NASA TM-88324 [N87-12967/NSP], [A02] "A Computational Method To Model Radar Return Range in a Polygonally Based, Computer-Generated-Imagery Simulation."*

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Telephone No. (703) 487-4650.
Rush orders may be placed for an extra fee by calling (800) 336-4700.

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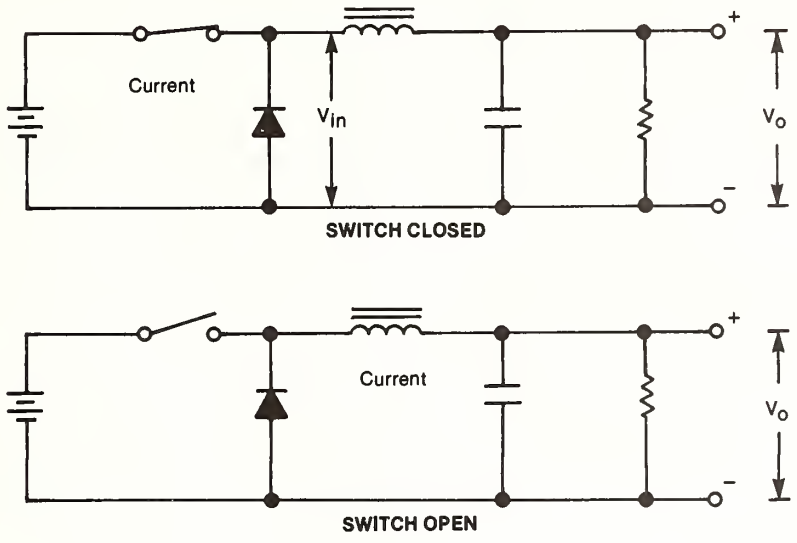
NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Switching Voltage Regulator

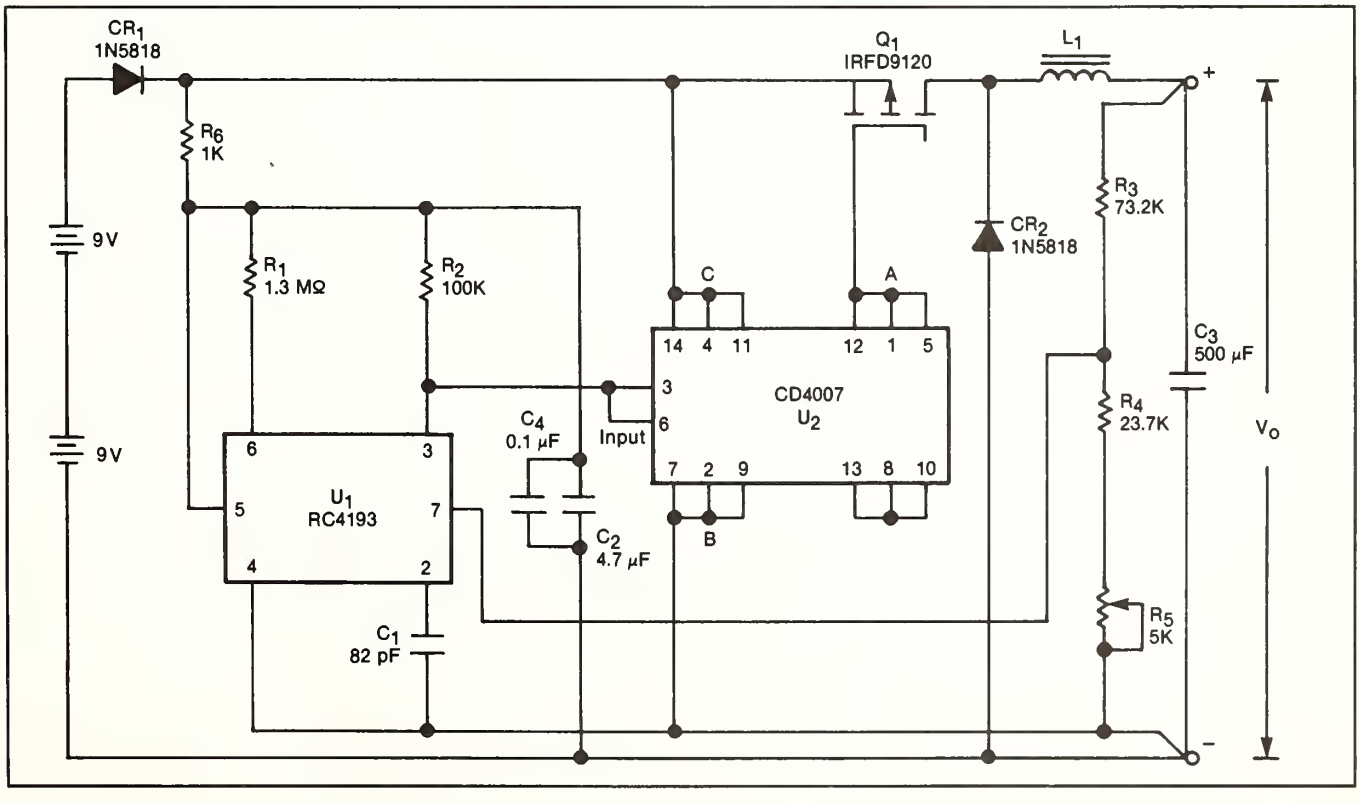
Both pulsed and continuous outputs are available.



A switching power-supply circuit converts the input power from two 9-V batteries in series to an output of 5 Vdc regulated within 1.5 percent, either at a continuous current of 5 mA or at a current of 500 mA in 0.5-s pulses at 1-min intervals. The power supply operates for at least 100 h on a pair of batteries. It is at least 50 percent efficient at a 5-mA load and 76 percent efficient at a 500-mA load.

Figure 1. This **Simplified Schematic Diagram** illustrates the principle of operation—inductive and capacitive filtering of controlled pulses of battery voltage.

Figure 2. This **Power Supply** converts unregulated 12- to 18-Vdc input to regulated 5-Vdc output.



The power supply is essentially a buck converter (see Figure 1). An electronic switch alternately connects the battery to and disconnects it from the input end of an inductor-and-capacitor filter. The inductor suppresses the input current transients, and the capacitor suppresses the output voltage transients. Provided that the switching frequency is much greater than the resonant frequency of the inductor-and-capacitor combination, the average dc output voltage V_o in the steady state is given approximately by

$$V_o = DV_{in}$$

where D = the duty cycle (the fraction of the switching cycle during which the switch is closed), and V_{in} = the input voltage (the battery voltage minus any voltage drop in the switching circuit).

The power supply (see Figure 2) maintains V_o nearly constant even though V_{in} decreases as the batteries are used up; it does this by sensing V_o and adjusting D accordingly. A voltage proportional to V_o is coupled to micropower switching-regulator integrated circuit U_1 via sensing resistors R_3, R_4, and R_5. Voltage V_o is set by choosing the ratio $R_3/(R_4 + R_5)$, and R_5 is adjusted to compensate for the tolerance in an internal Zener-diode voltage reference and associated components in U_1.

Circuit U_1 contains an oscillator, the frequency of which (of the order of 30 kHz) is determined in part by C_1. The sensed voltage on terminal 7 is compared with the internal reference voltage; the difference between them controls the duty cycle of a pulsed version of the oscillator signal at output terminal 3.

Transistor Q_1 is the power switch at the input end of inductor L_1. Integrated circuit U_2 serves as an analog multiplexer that alternately connects the gate of Q_1 to the negative side of the battery or to the source of Q_1, under the control of the output of U_1. Thus, pulses of battery voltage are applied to L_1 at the oscillator frequency and at a duty cycle controlled by V_o.

Inductor L_1 and capacitor C_3 must be chosen carefully to cope with transient loads and to remain within specified limits on size and weight. In this case, L_1 was chosen to be a swinging choke (a nonlinear inductor); as the current increases from light to heavy loads (from 5 to 500 mA), the core of L_1 saturates, causing the inductance to decrease from about 400 mH to 100 mH. Although a linear version of L_1 could be used, tests show that the nonlinear version responds better to transient loads.

This work was done by Colonel W. T. McLyman of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-16889/TN*

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NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

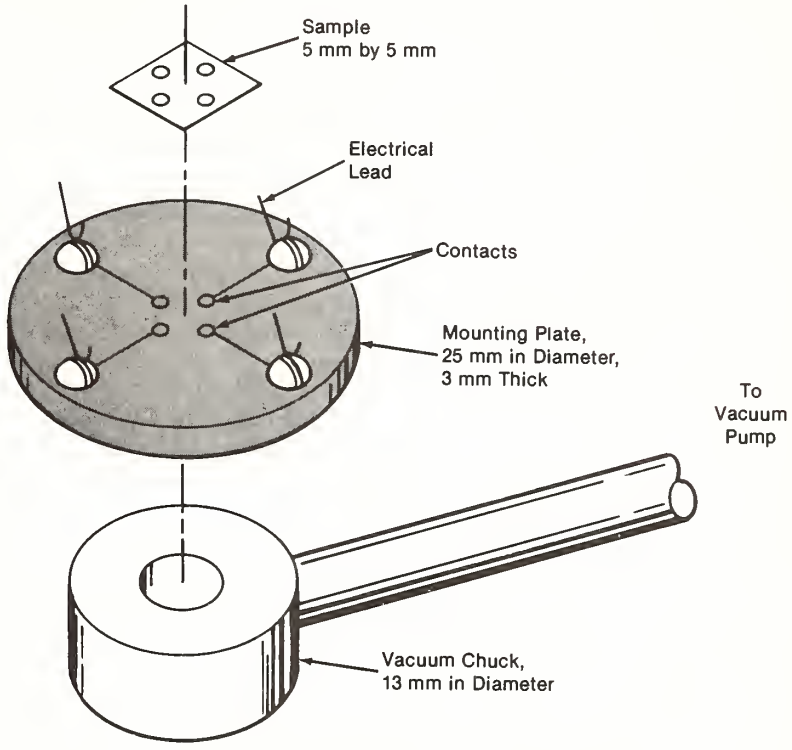
Mounting Thin Samples for Electrical Measurements

A vacuum chuck holds samples gently but securely.

A new method for mounting a thin sample for electrical measurements involves the use of a vacuum chuck to hold a ceramic mounting plate, which, in turn, holds the sample. Contacts on the mounting plate establish the electrical connection to the sample (see figure). The method has been used to make electrical measurements over the temperature range from 77 to 1,000 K and does not introduce distortions into the magnetic field during Hall measurements.

The mounting plate is made of a machinable, glass/ceramic insulating material. Both surfaces of the plate and the surface of the vacuum chuck are polished to enhance the vacuum seals between the various elements. Holes through the mounting plate communicate the vacuum, which is provided by a commercial Venturi pump, to the interface between the plate and the sample. Atmospheric pressure on the sample provides the mechanical force to hold the sample in place and to establish electrical contact.

The contacts on both the sample and the mounting plate are deposited by sputtering. The vacuum holes through the mounting plate are concentric with the contacts on the plate, which are in the form of conducting annuli. Each sample has a pattern of solid contacts identical to that of the mounting plate, and the contacts are positioned on the plate so that they are aligned over the conducting annuli. The contact pattern deposited on the mounting plate includes conductors extending from the conducting annuli to a second set of contacts near the periphery of the plate. The peripheral contacts are used to connect lead wires that, in turn, are connected to the appropriate measuring devices.



This **Exploded View** shows the scheme for mounting and making electrical contact to the sample.

This work was done by L. G. Matus and R. L. Summers of **Lewis Research Center**. *No further documentation is available.*
LEW-14646

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Isolated Data Acquisition In Hostile Environments

Fermilab's Linac, the first step in the Lab's chain of accelerators, satisfies its substantial rf power needs through the use of high-voltage equipment. Until recently, measurement of transient signals within these multi-deck modulators was accomplished with transformer couplings. Aside from the obvious disadvantages of cost and size, there was the ever-present risk of a tube-generated spark jumping across anbd destroying measuring equipment.

Capitalizing on low-cost, high-precision fiber optics, Fermilab engineers have developed an isolated data acquisition system that safely and rapidly gathers both analog and binary data from within those high-voltage environments.

The system is comprised of a microprocessor controller which communicates with remote data acquisition circuits via an optical serial bus. Upon receiving an initiation timing pulse, the controller sends addressed commands to individual remote cards and receives data in return. It then passes this data to a host system through a general-purpose parallel connection. Each remote circuit can return 16 binary senses and up to 7 12-bit analog parameters. High-speed response is assured through the use of a pipelined design wherein one word is transmitted while another is being converted. The system is configured to look like a VME card, and uses a standard protocol (MIL 1553) to minimize the chance of a transmission error going undetected.

This system would seem to be ideally suited to Linac modulator systems, power generation and distribution, and monitoring high-voltage/high-noise industrial processes where real-time process monitoring in required.

For Additional Information:

Office of Research and Technology Applications
Fermi National Accelerator Laboratory
P.O. Box 500
MS 208
Batavia, IL 60510
(312) 840-3333

Refer to FAA-306/TN

NAVY
Domestic Technology Transfer Fact Sheet

Optical Tool Characterizes Electronic Materials

At the Naval Research Laboratory (NRL), Washington, D.C., scientists have developed an optical characterization tool--*photoreflectance*--to determine the electrical properties of electronic materials.

Photoreflectance is a contactless, nondestructive tool that can be used to inspect semiconductor wafers before, during, and after the fabrication of microelectronic chips. A wafer is a base material upon which integrated transistor circuits are formed. The measurement using this technique is rapid, automated, and cost-effective. It helps identify wafers that have faults that arise in crystal growth and/or processing time and reduces chip failure.

Photoreflectance can determine important semiconductor characteristics, such as alloy composition and carrier concentration (and their spatial homogeneity) in a short time. The technique has also been used to assess crystal damage during ion-implantation and to determine the built-in strain in new semiconductor composites such as Gallium arsenide (GaAs) on silicon (Si). Photoreflectance is particularly useful in characterizing custom-made semiconductor microstructures such as superlattices and modulation-doped structures. The manufacturing of the structures requires control on an atomic scale to achieve the optical and electrical properties desired. Microstructure based electronics means faster computers, smaller and higher frequency microwave transmitters, and new multicolor chip lasers.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 130806/TN

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

NIST Expands Capabilities Of Anechoic Chamber

The NIST Electromagnetic Fields Division, Boulder, Colo., has expanded the capabilities of its electromagnetic (EM) anechoic chamber to meet the needs of government and industry. The facility, which measures 28 feel long, 12 feet wide, and 16 feet high, generates standard EM fields with minimum reflections and interference. Until now it was used to measure a variety of antennas and probes in the frequency range from 200 MHz to 18 GHz. One reason the frequency range has been expanded to 40 GHz is to calibrate hazard field probes that go up to 40 GHz. NIST will provide measurement services and special tests to meet customers' needs. Recent customers included the military services, Bell Aerospace Corp., and BI, Inc.

FOR ADDITIONAL INFORMATION: Contact Galen Koepke, Division 723.03, NIST, Boulder, CO 80303; (303) 497-5766.

Energy

0181 Experimental Studies of Heat and Mass Exchange in Parallel-Passage Rotary Desiccant Dehumidifiers for Solar Cooling Applications

0182 Specular Steel Surfaces for Solar Mirror Substrates

0183 Windows for the Future

0184 Rotary Joint for the Space Station—Earthbound solar-power systems could also benefit from this development.

Other Items of Interest

0171 Integrated Inverter and Battery Charger—A dual-function circuit would obviate duplication of electrical components and structural parts. (Licensing Opportunity)

Department of Energy

Technology Application

Solar Energy Research Institute

Experimental Studies of Heat and Mass Exchange in Parallel-Passage Rotary Desiccant Dehumidifiers for Solar Cooling Applications

This report describes the research associated with the performance of advanced, parallel-passage, rotary dehumidifiers for building conditioning. Descriptions of the experimental method and data analyses are provided. This research represents the first attempt to compare a detailed component model for a rotary desiccant dehumidifier with a complete set of experimental data for solar cooling applications. The model will help researchers and designers determine the tradeoffs that must be made among design and operating characteristics such as pressure loss, mass-transfer performance, cost, reliability, and aging.

FOR ADDITIONAL INFORMATION: A copy of this report is available from NTIS, Springfield, VA 22161; (703) 487-4600.

NTIS order number: DE88001117/NAL

Price code: A03

Solar Energy Research Institute

Specular Steel Surfaces for Solar Mirror Substrates

The long-range objective of the work reported here is to develop a process for making a silvered stainless steel mirror that has the optical performance and service life of a silvered glass mirror coupled with the mechanical durability, structural strength, and flexibility of sheet steel. Such reflectors are expected to minimize the cost of handling, fabricating, and shipping concentrators. Specifically, this work is designed to produce thin metal membranes with sufficiently fine surface finishes to serve as substrates for direct silver deposition, silvered polymer films, or silvered sol-gel coatings in heliostat, parabolic trough, and dish applications. This report addresses the relationship of optical quality to surface finish and the results of a cooperative research venture with a commercial sheet manufacturer to produce specular stainless steel surfaces by cold-rolling with highly polished rollers.

FOR ADDITIONAL INFORMATION: A copy of this report is available from NTIS, Springfield, VA 22161; (703) 487-4600.

NTIS order number: DE88001153/NAL

Price code: A03

Solar Energy Research Institute

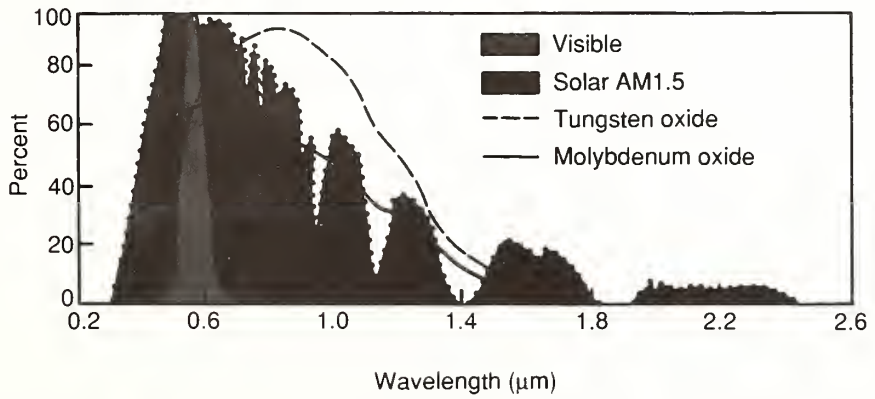
Windows for the Future

In the future, our homes and cars may be equipped with electrochromic windows. These windows, with a transparent, multilayer coating of metal oxide on the surface, will change from transparent to opaque when a voltage is applied to the coatings. Such window coatings will control automatically the amount of daylight and solar heat entering a building or vehicle and thereby reduce glare, air-conditioning requirements in the summer, and lighting energy costs, and make efficient use of solar heat gain in the winter.

A practical electrochromic window must be all of the following: functional, aesthetic, economical, and durable. A SERI-patented process holds promise for improving the economics and aesthetics of such windows.

The process is called plasma-enhanced chemical vapor deposition and is similar to processes used for producing amorphous silicon photovoltaic cells. Radio-frequency excitation of a gas mixture such as molybdenum hexacarbonyl ($Mo(CO)_6$) plus oxygen causes rapid interaction and deposition of the oxide (MoO_3) at room temperature and at very high rates (on the order of 80 nanometers per second). This high rate of film production and the low temperature of the process should help to reduce costs.

The electrochromic response of the molybdenum oxide is also aesthetically superior to other electrochromic



The optical absorption of electrochromic molybdenum oxide is more neutral in color than other electrochromic materials such as tungsten oxide. The nearly uniform absorption across the visible spectrum (gray) makes the molybdenum oxide film appear gray whereas the tungsten oxide is bright blue. Both materials block a large portion of the solar spectrum (orange).

materials such as tungsten oxide. The molybdenum oxide absorbs light much more uniformly across the visible spectrum and, therefore, appears more neutral in color.

The durability of electrochromic coatings made by the new process is now being tested.

For Additional Information:

Mr. Dana Moran
Research & Technology Application
Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401-3393
(303) 231-7115

NASA Tech Brief
National Aeronautics and Space Administration

Rotary Joint for the Space Station

Earthbound solar-power systems could also benefit from this development.

Solar-power-conversion units for the Space Station must be capable of tracking the Sun at an approximate orbital rate of 1 revolution per 94 minutes. The most critical mechanism aboard the station will be the rotary joint that performs this tracking function, because it must position the solar photovoltaic receiver and the solar dynamic collector to face the Sun within about 1° and 0.1°, respectively.

Due to the large inertias of these solar receivers and the lengths of the transfer booms, structural stiffness across the "alpha" joint must be maximized to reduce deflection and accelerations as well as to maximize the rate of response of the actuator. The joint must contain a rotary means to transfer electrical power and data signals across the rotary interface. Furthermore, the rotary drive mechanism must provide smooth motion, possess long life in a space environment, and have intrinsically fail-safe characteristics.

A study was conducted to determine the optimum mechanism for the rotary joint. The results of the study indicated that the best mechanism would be a continuously rotating joint based on the concept of a multiple, discrete bearing-supported joint driven by a self-loading, "pinch"-roller drive actuator.

This mechanism provides greater protection against catastrophic jamming, less sensitivity to adverse thermal gradients, greater accessibility to maintenance or replacement, and greater adaptability to very large truss members than do more-conventional continuous-support-bearing/gear joints. Furthermore, wear-life estimates show a continuous service life more than two orders of magnitude greater than that required for this application. This rotating-joint mechanism would be applicable not only to solar-power-conversion units but also to Earthbound solar-power farms and other related power-generation systems.

This work was done by Stuart H. Loewenthal and Fredrick T. Schuller of **Lewis Research Center**. *Further information may be found in NASA TM-88800 [N86-30206/NSP], [A03] "Feasibility Study of a Discrete Bearing/Roller Drive Rotary Joint for the Space Station."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650.
Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-14542/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Engineering

0185 Angular-Momentum-Compensating Actuator—A rotary actuator imparts no torque to its supporting base.

0186 Integrated Analysis of Static Distributed Systems—An integrated approach encompasses modeling, identification of parameters, estimation of states, and control.

0187 Manipulator for a Vacuum Chamber—A rotary seal provides for external actuators.

0188 Predicting Life and Reliability of a Rotating Disk—The effects of design variables, temperature gradients, and speeds are examined.

0189 Semiautomatic Probe-and-Drogue Attachment Mechanism—Spring-loaded pawls would provide quick coupling.

0190 Stacked-Disk Combustor—Materials could be chosen for strength rather than for thermal conductivity.

0191 Stand for Infrared Multiple-Internal-Reflection Mount—Infrared MIR spectra are more reproducible, and MIR crystal suffers less damage.

0192 Status of Sorption Cryogenic Refrigeration—Present equipment and anticipated development are described.

Software

0193 Plane Frame Computer Program

0194 Space Frame Computer Program

0195 Space Truss Computer Program

Testing & Instrumentation

0196 Bearing/Bypass Material-Testing System—The system maintains a constant ratio of bearing to bypass loading during testing. (Licensing Opportunity)

0197 Laminar-Separation Sensor—The sensor detects flow reversal in a boundary layer.

0198 Multiple-Coil, Pulse-Induction Metal Detector—A large area is scanned rapidly. (Licensing Opportunity)

Other Items of Interest

0178 Isolated Data Acquisition in Hostile Environments

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

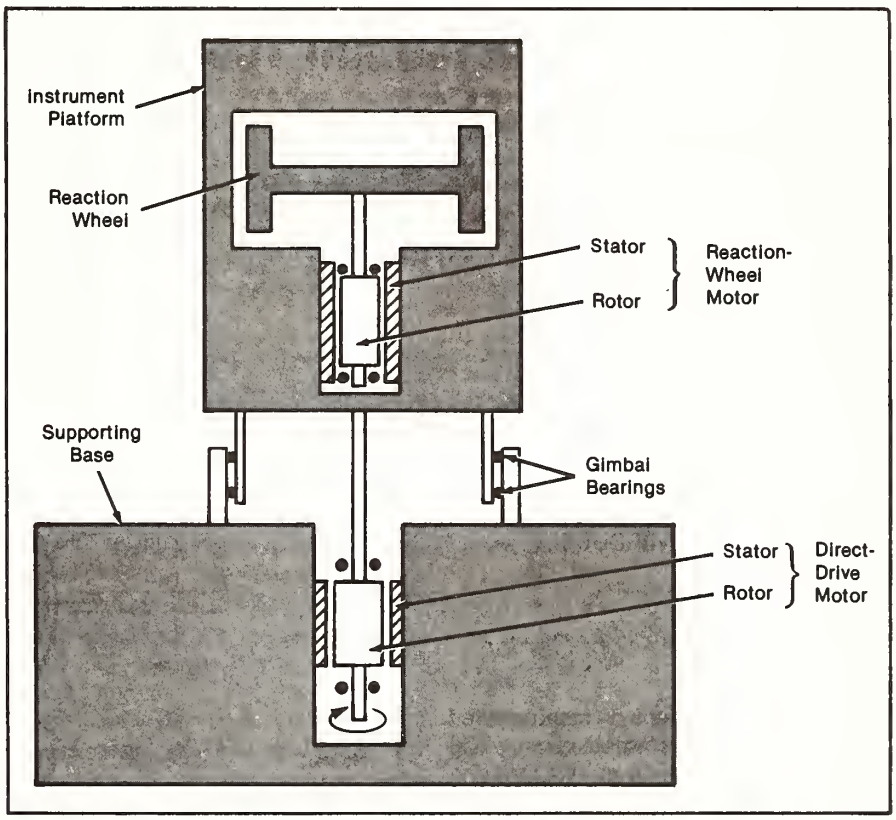
Angular-Momentum-Compensating Actuator

A rotary actuator imparts no torque to its supporting base.

A precise aiming actuator for an instrument platform suppresses reactions in its supporting body to the torques that occur when the aiming angle is changed. The reactionless actuator was developed for instrument-pointing platforms on flexible spacecraft; by eliminating reactions, the actuator can change the aiming angle of the platform without inducing vibrations in the spacecraft, which in turn eliminates vibrations in the pointing angle of the instrument platform. The absence of reactions also makes it unnecessary to use thrustor fuel to correct for angular momentum imparted to the spacecraft when an instrument is pointed in a new direction. The actuator can be used on Earth in such systems as helicopter platforms for television cameras in law enforcement and news telecasts.

The actuator employs a pair of counter-rotating brushless dc motors on a common axis (see figure). The direct-drive motor applies torque between the supporting base and the instrument platform to compensate for the torques exerted by friction and by the bending of cables in the rotary joint between the platform and the base. The reaction-wheel motor applies torque between the platform and a reaction wheel to turn the platform.

The motors are commutated electronically by a hybrid analog/digital control system that responds to a platform-turning-rate command and to turning-rate feedback signals from angle resolvers in the motors and from a turning-rate gyroscope on the platform. The control system issues torque commands to the motor-drive electronics according to a control algorithm that strives continually for zero net torque on the supporting base. The control algorithm also strives to prevent the excessive buildup of angular momentum in the reaction wheel.



The **Reaction Wheel** negates the effects of torque and angular momentum of the rotating platform. The direct-drive motor replaces the energy lost to bearing friction and to torque exerted by electrical cables.

This work was done by Peter J. Wiktor of Caltech for **NASA's Jet Propulsion Laboratory.**
NPO-16928 /TN

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NASA Tech Brief
National Aeronautics and Space Administration

Integrated Analysis of Static Distributed Systems

An integrated approach encompasses modeling, identification of parameters, estimation of states, and control.

A report discusses aspects of an integrated methodology for the mathematical modeling, identification of parameters, and estimation of the states of a structure or other distributed system, for the purpose of controlling the system. The approach is appropriate for systems in which time-dependent effects are negligible and where control forces can be applied without exciting significant dynamic behavior.

The approach applies to models specified in part by possibly interconnected elliptic partial differential equations for deflections of structures under static loads. The authors cite the example of a wrap-rib antenna equipped with deflection sensors and with actuators that alter its reflecting surface. In this case, the mathematical model also provides for the analysis of measurements of the electromagnetic far field, which is affected by the deflections and can therefore be used to infer the deflections.

Errors in the mathematical model and in the measurements are treated as white noise; this leads to a second-order analysis of the related statistical errors. The identification (that is, the parameter-estimation) techniques are based on the method of maximum likelihood, in which the values of parameters in the mathematical model are obtained by maximizing an appropriately-defined likelihood functional that corresponds to the model equations and that incorporates the measurements. The maximization procedure is based on a Newton iteration of the functional, involving simultaneous approximations in the state and parameter spaces.

The state is estimated by use of a derived conditional mean of the state, given the measurements and parameter values. The resulting estimate is represented as a least-squares superposition of shape functions derived from the model of the structure. Batch processing of different kinds of measurements (e.g., deflections measured at a limited number of points on the antenna or far-field data taken at a finite number of points) yields recursive formulations for the state estimate similar to Kalman gains.

Computer simulations have demonstrated the validity of the general approach. A simplified model of the wrap-rib antenna with 6 actuators and 6, 9, or 12 deflection sensors yielded fairly accurate estimates of the rib-stiffness parameters, with little improvement as the number of sensors was increased. With a simplified planar antenna model, the approach yielded a small spurious deflection in a state-estimation test that used simulated far-field measurements along a ring and simulated electro-optical deflection measurements along a ring and at the center of the antenna surface.

This work was done by Guillermo Rodriguez and Robert E. Scheid, Jr., of Caltech for **NASA's Jet Propulsion Laboratory**. *"Integrated Approach to Modeling, Control, Estimation and Identification for Static Distributed Systems," NPO-17010/TN*

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NASA Tech Brief
National Aeronautics and Space Administration
Goddard Space Flight Center, Greenbelt, Maryland

Manipulator for a Vacuum Chamber

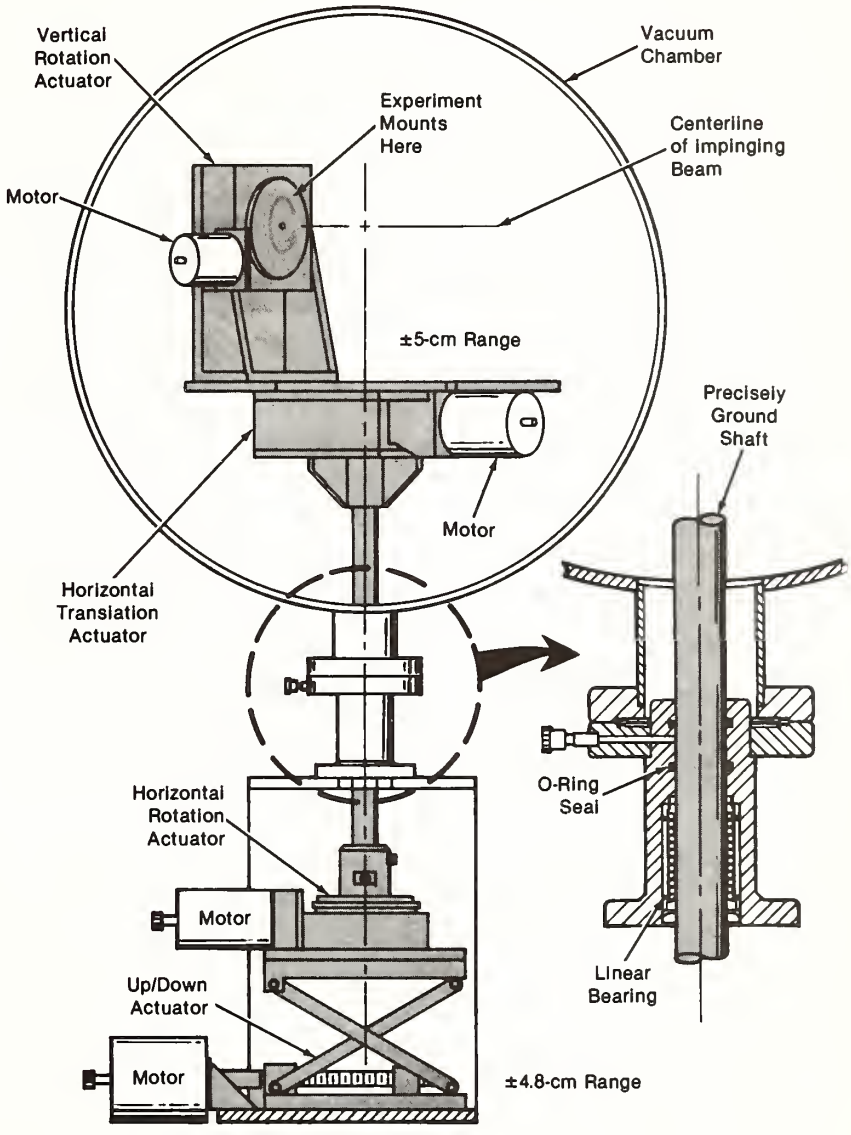
A rotary seal provides for external actuators.

A manipulator precisely positions objects in a vacuum chamber. The motion of the externally driven manipulator does not appreciably increase demands on the vacuum pump at pressures as low as 10^{-7} torr (about 10^{-5} Pa). The manipulator was developed for calibrating plasma detectors by subjecting them to particle beams in a vacuum. Standard, commercially available parts are used.

External up/down and azimuthal actuators drive a shaft that enters the vacuum chamber through a sliding and rotating seal (see figure). The placement of the actuator motors outside the vacuum chamber reduces the heat-removal load on the system. Atop the 2.5-cm-diameter shaft is a stage that can support masses as great as 15 kg. Small motors on the stage provide horizontal translation and rotation in a vertical plane.

A computer controls the motors and measures angles and positions, providing an accurate and convenient readout. Vertical and horizontal positioning is precise to ±25 μm. The angular precision is ±0.01°.

This work was done by F. Hunsaker and K. Ogilvie of **Goddard Space Flight Center**. *No further documentation is available.*
GSC-13130 /TN



The Positioner in the Vacuum employs four actuators: up/down, horizontal rotary, horizontal, and vertical rotary.

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NASA Tech Brief
National Aeronautics and Space Administration

Predicting Life and Reliability of a Rotating Disk

The effects of design variables, temperature gradients, and speeds are examined.

A report presents a study of a generalized method for the prediction of the fatigue life and the reliability of a rotating disk. The method incorporates the computation of the life, at a given probability of survival, of elemental stressed volumes within the body of the disk.

The effects of speed and of such design variables as the diameter and thickness of the disk and the size, number, and location of boltholes on the life of the disk were determined. An investigation into the effect of a radial temperature gradient as well as the accompanying induced thermal stresses on the relative life of the disk was also performed. In addition, such characteristics of the material as the Weibull modulus and fatigue limit were incorporated into the method.

From the analysis, the concept of a dynamic-speed capacity, N_0, is introduced. This is defined as the speed that would produce a theoretical life of one million stress cycles at a 90-percent probability of survival. For any speed, N, the life, L, for a given disk at a 90-percent probability of survival is

$$L = \left(\frac{N_0}{N}\right)^{14.3} \times 10^6$$

This method would be useful in the analysis, design, and development of disks for aircraft-engine turbines and compressors and flywheels for industrial and automotive applications.

This work was done by Erwin V. Zaretsky of **Lewis Research Center** *and Todd E. Smith and Richard August of Sverdrup Technology, Inc. Further information may be found in NASA TM-88883 [N87-13755/NSP], [A03] "Effect of Design Variables, Temperature Gradients, and Speed of Life and Reliability of a Rotating Disk."*

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NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Semiautomatic Probe-and-Drogue Attachment Mechanism

Spring-loaded pawls would provide quick coupling.

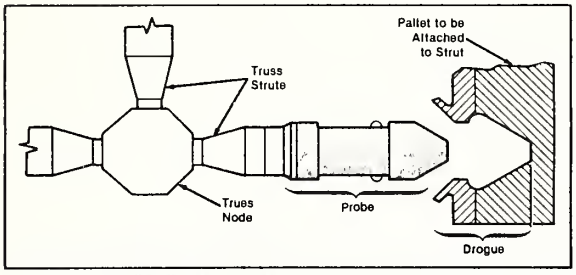

Figure 1. The **Probe-end-Drogue Mechenism** could be used to attach and detach components of modular structures.

In a proposed probe-and-drogue attachment mechanism, all of the active components are in the probe. The drogue is a simple fixed cavity, which should require no maintenance. Previous designs had active drogue mechanisms, which would be difficult to replace if damaged.

The proposed probe-and-drogue mechanism is suitable for the attachment of components that must later be disconnected (see Figure 1). Precise alignment is not required prior to coupling, but is achieved after coupling by extending a locking cap. The new mechanism was originally proposed for attaching modules to the Space Station without requiring extravehicular or other astronaut activity. It should be useful for coupling modular components in other applications where ease and security of attachment, precise final alignment, and ease of removal are important and where stresses and bending moments are reasonably low.

As the probe enters the drogue during coupling (see Figure 2), three spring-loaded pawls in the probe latch the probe in the drogue, preventing accidental uncoupling. Then a worm-gear mechanism turned by a standard 0.25-in. (6.35-mm) tool transfers motion to a central threaded shaft, which extends the cap at the tip of the probe until all play is taken up. This centers the probe in the drogue and renders the coupling rigid.

To uncouple the probe, the worm gear is turned in the opposite direction to retract the probe cap. As it retracts, the rear of the cap depresses the three pawls into the body of the probe. This frees the probe for easy removal. Prior to recoupling, the cap must be partially reextended to allow the pawls to extend again.

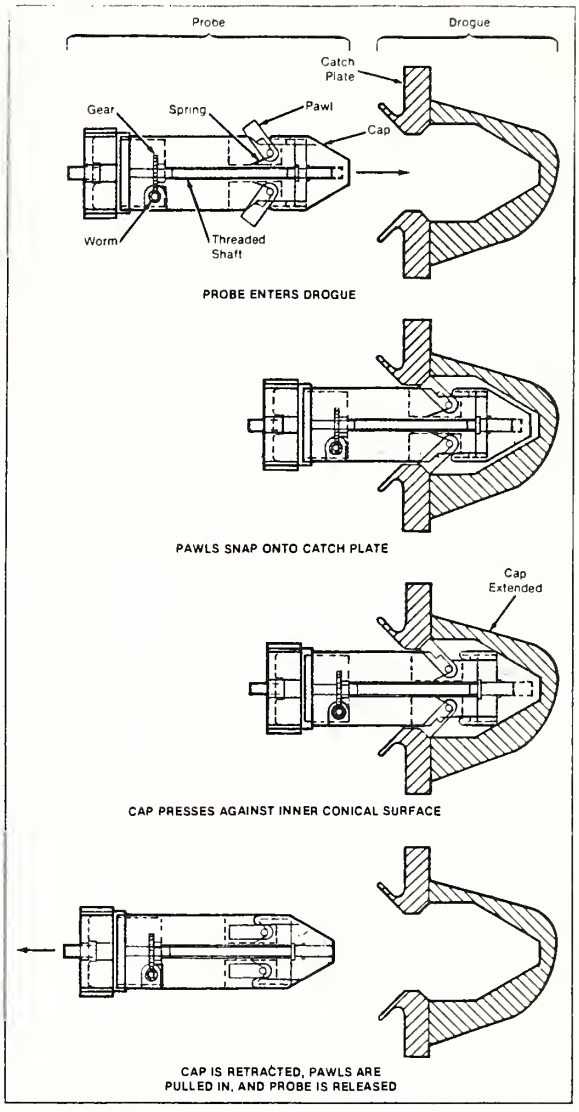

Figure 2. **Spring-Loaded Pawls** latch automatically when the probe enters the drogue. The probe is locked in position when the cap is forced against the inner conical surface of the drogue. To disconnect the probe from the drogue, the cap is retracted enough to cause the pawls to fold into the body of the probe.

This work was done by John D. Wanagas of Rockwell International Corp. for **Johnson Space Center**. *No further documentation is available.*
MSC-21254 /TN

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Stacked-Disk Combustor

Materials could be chosen for strength rather than for thermal conductivity.

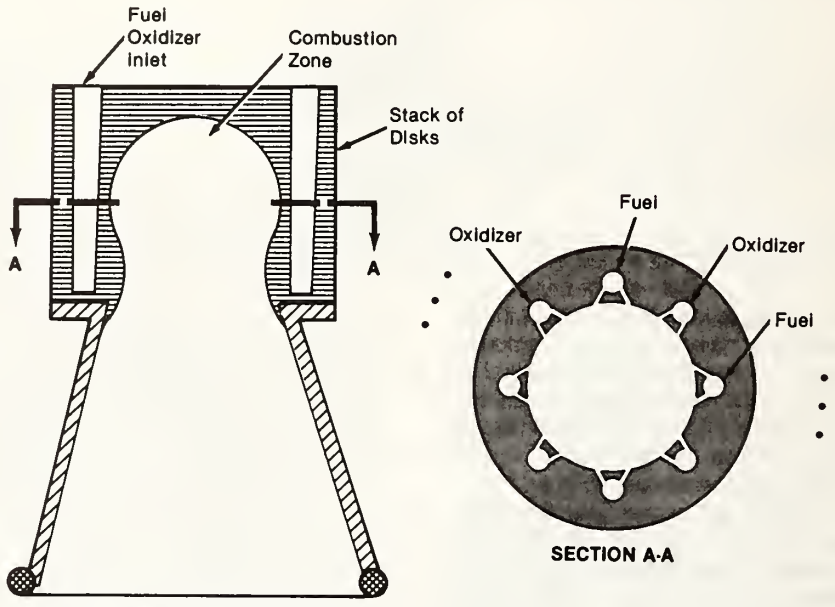
A proposed combustion chamber for turbine or rocket engines would be constructed of stacked disks. The disks would be successively shaped to provide the required aerothermodynamic contour in the chamber and would incorporate internal cooling passages. Clamped and diffusion-bonded or otherwise bonded together, the stacked disks would form a combustion chamber that could be operated for greater efficiency at pressures and temperatures higher than those of a conventional tube-wall combustion chamber.

With leakproof internal transpiration cooling of the chamber, the disk material could be chosen primarily for strength rather than as a compromise between strength and heat conductivity. The weight of the combustion system or engine may be reduced as a result.

The disks would be made of thin sheets, perhaps 3 to 5 mils (76 to 127 μm) in thickness. They would be cut to the requisite shapes inexpensively by photolithographic masking and etching. The patterns might be established by computer-aided design and executed automatically at high production rates.

This work was done by Walter B. Ingle of Rockwell International Corp. for **Marshall Space Flight Center.**

MFS-29333 /TN



Stacked Washerlike Disks would accommodate built-in coolant passages while providing a combustion zone of ideal shape. Fuel would flow through the coolant passages where it would be preheated before entering the combustion zone through passages in the disks. Here, eight coolant passages are shown in the cross section, although the number in a particular application would be determined by the required rate of flow of fuel and pressure drop.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

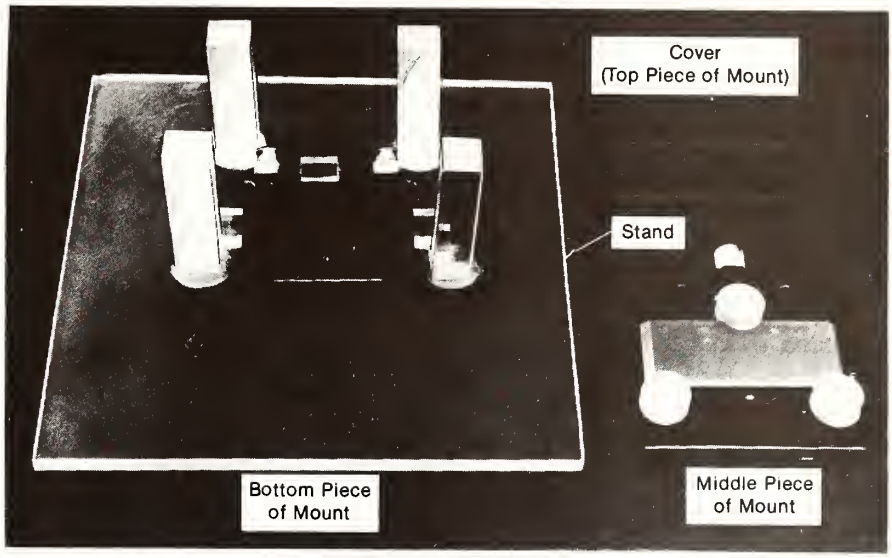
Stand for Infrared Multiple-Internal-Reflection Mount

Infrared MIR spectra are more reproducible, and MIR crystal suffers less damage.

A new technique prevents lateral movement between the elements in a multiple-internal-reflection (MIR) cell during its assembly. The cell is used in infrared spectroscopy. The reproducibility of infrared MIR spectra relies on the ability to maintain the condition of the crystal, which is the MIR element, and to control the contact between the crystal and the sample. A newly developed yet simple stand does both by eliminating the movement of the mount pieces as pressure is applied and by providing a more consistent way of handling the specimen.

The stand aligns a three-piece mount (see figure), which holds a crystal and a specimen for infrared MIR spectroscopy. The mount is stacked vertically beginning with a bottom piece, which can hold either a liquid or an additional solid sample. A middle piece, which contains the crystal with a solid sample behind, is placed over the bottom piece with the crystal facing down, matching a triangular arrangement of holes. A cover, which supplies the pressure, is oriented with its three holes in the same manner as that of the first two pieces.

Screws are placed into the three holes and tightened. This assembly stand prevents the movement of the pieces of the mount during the tightening process and thereby prevents the scratching of the crystal. (The scratching of the crystal would reduce the sharpness of the spectrum, resulting in a loss of information.)



The **Simple Design of the Stand** facilitates the accommodation of any commercially-available mount system.

The stand is constructed of acrylic pieces bonded with epoxy adhesive. On the base are columns of two lengths. The three shorter columns match the thickness of the bottom piece of the mount and hold this piece in place. The four longer columns exceed the total thickness of the three pieces of the mount to accommodate any thickness of sample. These longer columns securely hold the center piece, which contains the crystal, and maintain the position of the top piece, which is as wide as the middle section.

The stand greatly reduces the marring of the crystal caused by the relative movement of the components of the mount/crystal/specimen stack during assembly. The lifetime of the crystal is increased by approximately an order of magnitude. In addition, the stand reduces the time spent mounting the specimen and increases the reproducibility of the infrared spectra.

This work was done by Edward R. Long, Jr., of **Langley Research Center** *and Cynthia A. Bradbury of Old Dominion University. No further documentation is available.*
LAR-13610/TN

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NASA Tech Brief
National Aeronautics and Space Administration

Status of Sorption Cryogenic Refrigeration

Present equipment and anticipated development are described.

A report reviews the state of the art in sorption refrigeration. Developed in recent years for cooling infrared detectors, for cryogenic research, and for other advanced applications, sorption refrigerators have few moving parts, little vibration, and lifetimes of 10 years or more. The report describes the types of sorption stages, multistage and hybrid refrigeration systems, power requirements, cooling capacities, and the advantages and disadvantages of the various stages and systems.

In sorption refrigeration, low pressure gas is sorbed by physical adsorption (physisorption) on the surface of a material or by chemical absorption (chemisorption) within a solid material (the sorbent). The sorbent is then heated by 100 to 200 °C to desorb the gas at high pressure. The pressurized gas is passed through precooling stages, then expanded in a Joule-Thomson valve where it is partially liquefied and cooled to the final low temperature. The boiling of the liquid removes the heat from the equipment cooled by the low-temperature stage. The low pressure boiloff gas is then reabsorbed by the sorbents, thus completing the cycle.

Rules have been formulated to aid the selection and design of sorption stages to minimize the overall power consumptions and weights of refrigeration systems. The following Joule-Thomson stages and assemblies are recommended accordingly:

- Physisorption of methane on carbon to attain a temperature of 150 to 110 K;
- The preceding stage plus chemisorption of O_2 on $Pr_{1-n}Ce_nO_x$ to attain 90 to 55 K;
- The preceding stages plus chemisorption of H_2 on $LaNi_{4.5}Al_{0.5}$ to attain 30 to 14 K; and
- The immediately preceding system with the H_2 stage augmented by chemisorption of H_2 on slightly cooled palladium or similar material to lower the vapor pressure over the liquid hydrogen, causing it to solidify and sublime at 10 to 7 K.

Nonsorption stages can be combined with sorption stages to reach lower temperatures. A mechanical-compressor J-T helium system can be operated in conjunction with the 14-K hydrogen-chemisorption stage to reach 4 to 5 K. Such temperatures could also be reached by adiabatic demagnetization in series with a hydride stage or with helium physisorption, although this particular sorption stage is extremely inefficient. Future progress in 4 to 5 K long-life refrigerators will probably require the development of nonlubricated mechanical helium compressors or improved cryogenic regenerators for use in Gifford-McMahon or Sterling expansion schemes.

This work was done by Jack A. Jones of Caltech for **NASA's Jet Propulsion Laboratory**. *"Sorption Cryogenic Refrigeration — Status and Future," NPO-17349 /TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

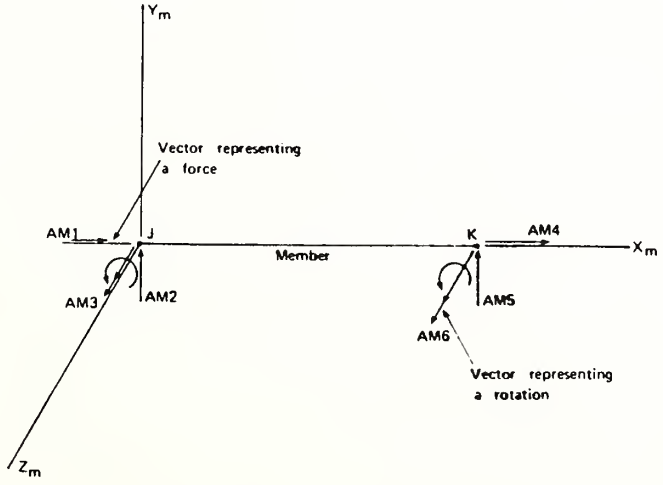
NCEL
Techdata Sheet

NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

Plane Frame Computer Program

A library of ocmputer programs has been developed by NCEL to individually analyze six common structural and civil engineering problems. These computer programs, called Structural Analysis Code Kit ("SACK"), augment the NAVFAC library of GEMS micro-computer programs by focusing on the field engineer's requirements to check analysis and design work performed by contract. By using the described methods, Public Works and Engineering Field Division engineers can rapidly evaluate probably 80% of the structural designs encountered in typical Navy facilities.

This program analyzes plane frames of prismatic bars that take axial loads, shear forces, and moments. Presently, it can handle frames having 50 members and 50 joints. Any joint can be given vertical, horizontal, and angular displacements. The data input may be modified to consider a composite frame. If members are going to take axial loads only, such as tie rods, make the moments of inertia very small and use the actual areas. Hinges can be accounted for by placing a short, flimsy member at the desired hinge location. The program has the capacity to divide a straight line between two points into any number of equal spaces. The only limitation on this feature is that a support (a joint which has restraint of some kind) cannot be between the first node and last node of the line being divided. This part of the program is optional.



Typical axes orientation for a plane frame member; positive direction shown.

Specifically, this computer program:

- Is free from proprietary limitations
- Is smaller in scope than large commercial programs
- Is very simple to understand and use
- Runs on an IBM-PC, XT, or AT or IBM compatible
- Is stored on a 360K floppy diskette
- Can be automatically booted from the floppy diskette or installed on a hard disk
- Will not become obsolete when new building codes are developed
- Comes with user manual and instructions
- Can be taught in a one-day session; arrangements can be made through the NCEL contact

This program has been extensively tested at the Naval Construction Battalion Center, Port Hueneme, and the Pacific Missile Test Center, Point Mugu, where it has proven reliable in solving typical structural problems.

FOR ADDITIONAL INFORMATION: contact Jerry Dummer, Code L03C, Facilities Engineering Support Office; (805) 982-4070. Refer to 88-06/TN.

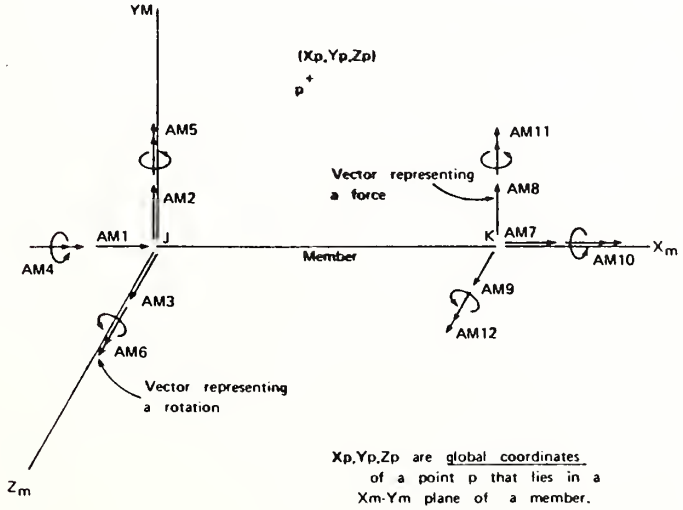
NCEL
Techdata Sheet

NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

Space Frame Computer Program

A library of computer programs has been developed by NCEL to individually analyze six common structural and civil engineering problems. These computer programs, called Structural Analysis Code Kit ("SACK"), augment the NAVFAC library of GEMS micro-computer programs by focusing on the field engineer's requirements to check analysis and design work performed by contract. By using the described methods, Public Works and Engineering Field Division engineers can rapidly evaluate probably 80% of the structural designs encountered in typical Navy facilities.

This program analyzes space frames of prismatic bars that take axial loads, shear forces, tension, and moments. Presently, it can handle frames having 50 members and 25 joints. Any joint can be given vertical, horizontal, and angular displacements. The data input may be modified to consider a composite frame. If members are going to take axial loads only, such as tie rods, make the moments of inertia very small and use the actual areas. Hinges can be accounted for by placing a short, flimsy member at the desired hinge location.



Typical axes orientation for a space frame member; positive direction shown.

Specifically, this computer program:

- Is free from proprietary limitations
- Is smaller in scope than large commercial programs
- Is very simple to understand and use
- Runs on an IBM-PC, XT, or AT or IBM compatible
- Is stored on two 360K floppy diskettes
- Is run on a hard disk
- Will not become obsolete when new building codes are developed
- Comes with user manual and instructions
- Can be taught in a one-day session; arrangements can be made through the NCEL contact

This program has been extensively tested at the Naval Construction Battalion Center, Port Hueneme, and the Pacific Missile Test Center, Point Mugu, where it has proven reliable in solving typical structural problems.

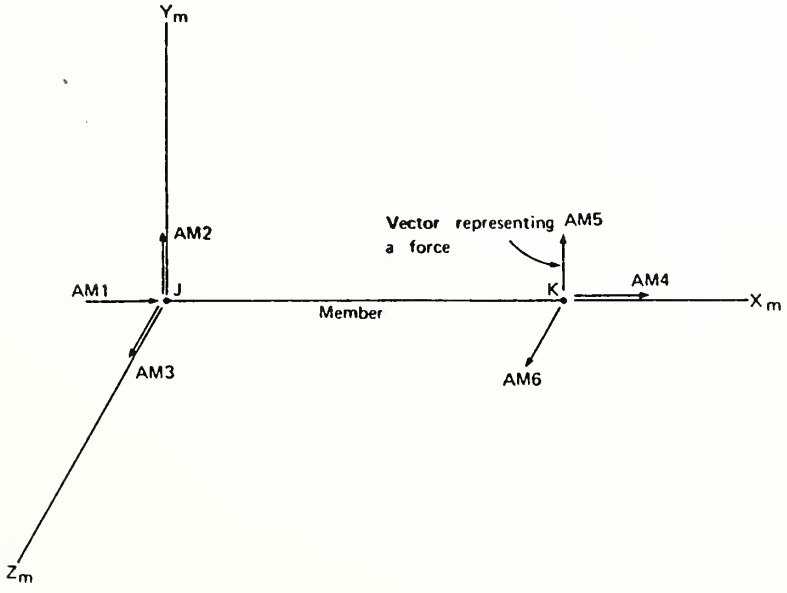
FOR ADDITIONAL INFORMATION: contact Jerry Dummer, Code L03C, Facilities Engineering Support Office; (805) 982-4070. Refer to 88-10.

NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

Space Truss Computer Program

A library of computer programs has been developed by NCEL to individually analyze six common structural and civil engineering problems. These computer programs, called Structural Analysis Code Kit ("SACK"), augment the NAVFAC library of GEMS micro-computer programs by focusing on the field engineer's requirements to check analysis and design work performed by contract. By using the described methods, Public Works and Engineering Field Division engineers can rapidly evaluate probably 80% of the structural designs encountered in typical Navy facilities.

This program analyzes space trusses of prismatic bars that take axial loads and shear forces. Presently, it can handle trusses having 150 members and 50 joints. Any joint can be given vertical and horizontal displacements.



Typical axes orientation for a space truss member; positive directions shown.

Specifically, this computer program:

- Is free from proprietary limitations
- Is smaller in scope than large commercial programs
- Is very simple to understand and use
- Runs on an IBM-PC, XT, or AT or IBM compatible
- Is stored on a 360K floppy diskette
- Can be automatically booted from the floppy diskette or installed on a hard disk
- Will not become obsolete when new building codes are developed
- Comes with user manual and instructions
- Can be taught in a one-day session; arrangements can be made through the NCEL contact

This program has been extensively tested at the Naval Construction Battalion Center, Port Hueneme, and the Pacific Missile Test Center, Point Mugu, where it has proven reliable in solving typical structural problems.

FOR ADDITIONAL INFORMATION: contact Jerry Dummer, Code L03C, Facilities Engineering Support Office; (805) 982-4070. Refer to 88-09/TN.

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Bearing/Bypass Material-Testing System

The system maintains a constant ratio of bearing to bypass loading during testing.

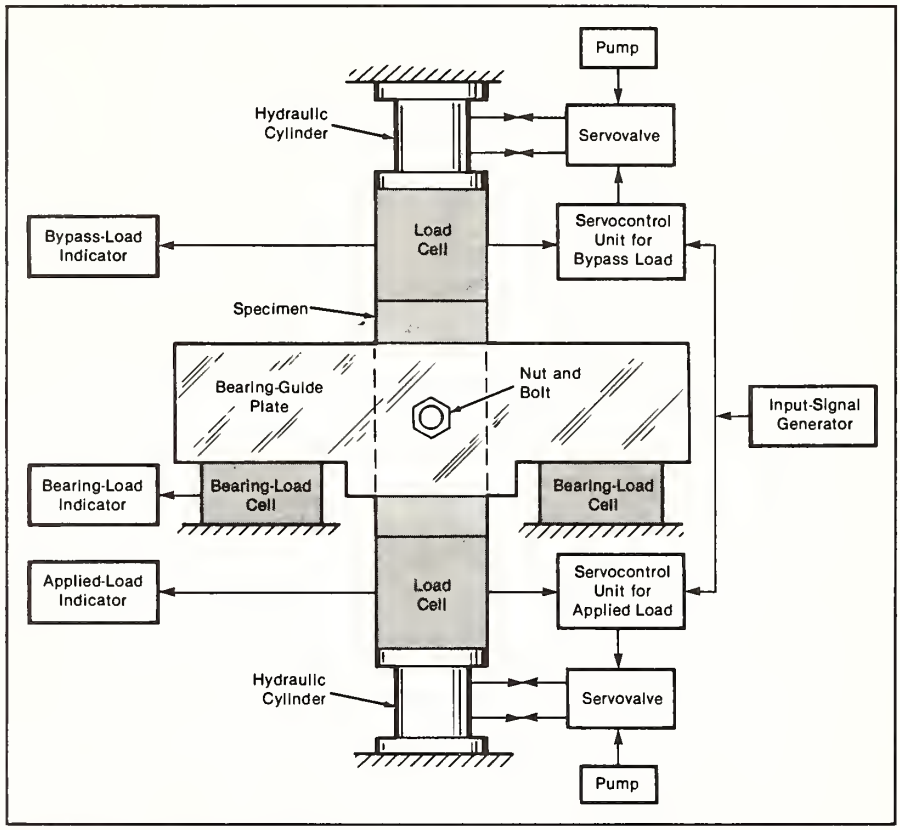
Structural failures often originate at fastener holes in joints. The local loading near a fastener typically consists of two components: (1) a bearing load component that is reacted at the hole and (2) a "bypass" load that is reacted elsewhere. In general, failures at holes are governed by the combined action of these two load components. As a result, material-evaluation tests for joints should include the combined effects of bearing and bypass loading. In such tests, a wide range of tension-and compression-load combinations are needed to represent fastener-hole conditions, but for each combination the ratio of bearing load to bypass load is nearly constant.

The currently used methods for combined bearing/bypass testing are either limited to tensile loading or cannot maintain constant bearing/bypass load ratios throughout the testing. The present system was developed to test specimens in compression as well as tension while maintaining a constant bearing/bypass ratio.

A test specimen with a centrally located hole is clamped between two bearing-guide plates using one bolt, as shown in the figure. The bearing-guide plates are then secured to the two bearing-load cells. The test specimen is independently loaded at both ends, using two separate control systems identified as applied and bypass. If the two end loads are unequal, the difference between them is reacted as a bolt-bearing load on the specimen.

Throughout the test, the two control systems are synchronized by a common input signal (an increasing voltage). As a result, the loads remain proportional as they increase. Maintaining a constant ratio between the two end loads produces the desired constant bearing/bypass load ratio. The two loading systems can be adjusted to produce any desired value of bearing/bypass ratio. The loads on the specimen are recorded as it is loaded to failure.

The bearing/bypass material-testing system works equally well in tension and compression. When testing in compression, the bearing-guide plates prevent the specimen from buckling. Fatigue bearing/bypass loading can also be created by using a cyclic input signal.



The **Bearing/Bypass Testing System** works equally well in tension and compression. It can also be used in cyclic testing.

This work was done by John H. Crews, Jr., of **Langley Research Center**. *Further information may be found in NASA TM-87705 [N86-23660/NSP] "Combined Bearing and Bypass Loading on a Graphite/Epoxy Laminate".*

Copies may be purchased [Price Code: A03] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center Refer to LAR-13458 /TN

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

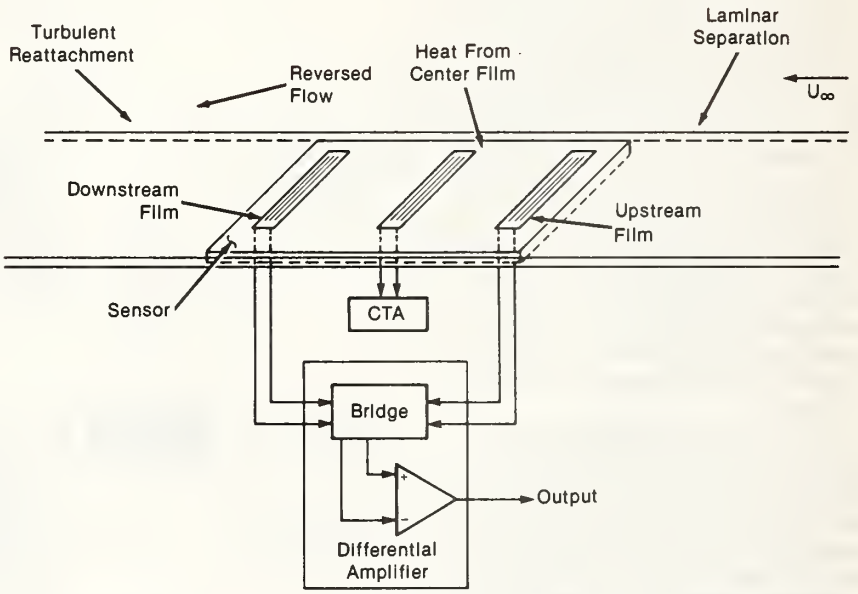
Laminar-Separation Sensor

The sensor detects flow reversal in a boundary layer.

The accurate determination on laminar-flow surfaces of the location and cause of the boundary-layer transition from laminar to turbulent flow is important in basic research for the validation of theory and in developmental testing for the validation of design. Laminar boundary layers form in an accelerating flow with velocity components in the downstream direction. When the local flow decelerates, a laminar-separation bubble can form in the boundary layer. Within the bubble, at the surface, the flow direction is reversed so that the local flow is in the upstream direction. The resultant velocity profile is inflected. Transition to turbulence may occur along the free shear layer over the top of the bubble. The existence of laminar separation in the boundary layer may thus be detected using a method that senses the direction of local flow at the surface.

The laminar-separation sensor provides a means for detecting a laminar-separation bubble by the use of a very thin, surface-mounted sensor. The sensor consists of a flush array of three proximate thin films, as shown in the figure. The middle film is electronically heated by means of a constant-temperature anemometer (CTA). The outer films, one upstream and one downstream of the middle film, are incorporated into a bridge circuit to respond as resistance thermometers.

When the sensor is exposed to flow, the heat from the middle film is transferred to either the upstream or downstream resistance thermometer, depending on the direction of the flow. The differential heating of the resistance thermometers is measured by a differential amplifier, and the direction of flow becomes evident from the direction of the signal output. By the proper selection of the film spacing (h), the sensor signals can be made to respond to the smallest laminar-separation bubbles of practical interest. The approximate spacing between elements for typical high-speed subsonic applications is 0.0625 in. (1.59 mm) or less. The orientation of the long dimension of the sensing element in the spanwise direction provides for greater sensitivity of the element to small laminar bubbles.



The **Laminar-Separation Sensor** is a flush array of three thin-film elements placed along a streamline.

The three elements consist of a series of polymer-backed thin-film nickel sensors that are dissected to create a predetermined sensor configuration and electrical resistance. They are then placed in a matrix on a thin polymer sheet and bonded with a suitable adhesive. The resulting sensor thickness is small enough not to cause boundary-layer transition to turbulence in most applications of interest. The CTA's used to heat the middle films are commercially available units, and the film elements are designed to be compatible with these units.

The nominal resistance of a film is 6.5 ohms or greater to provide the necessary sensitivity. Since the sensors can be manufactured with very uniform resistances, several middle films can be multiplexed onto one anemometer with no adjustment to the system. The sensors can be installed in a staggered fashion or fabricated into one continuous multielement strip of sensors, providing for the measurement of the streamwise movement of laminar separation with changes in the angle of attack.

This sensor is easier to install and involves less circuitry than do systems involving three surface-buried hot wires. In flight at high Reynolds numbers, where the length of a laminar separation bubble may be quite small, this sensor provides the only known surface-mounted means for positively identifying the presence of laminar separation as a cause of boundary-layer transition.

This work was done by Bruce J. Holmes, Harlan K. Holmes, Thomas C. Moore, Gregory S. Manuel, and Cynthia C. Croom of **Langley Research Center** *and Debra L. Carraway of Old Dominion University.*
LAR-13463/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
John F. Kennedy Space Center, Florida

Licensing Opportunity

Multiple-Coil, Pulse-Induction Metal Detector

A large area is scanned rapidly.

A multiple-head, pulse-induction metal detector scans an area of 72 ft^2 (6.7 m^2) with a combination of eight detector heads, each 3 ft (0.9 m) square. The new detector, designed for the recovery of Space Shuttle debris, replaces an earlier version that had only one 3-ft-square head and that was based on the tuned-coil principle.

In the tuned-coil principle, the resonant frequency of the coil in the detector head is changed by the detected metal. This principle is not suitable for a multiple-head detector because each head would have to be tuned to a different frequency, and this would entail an impractically large bandwidth. However, the pulse-induction method used in the new detector is suitable for multiplexed operation and does not impose a severe bandwidth requirement.

Each detector head (see Figure 1) includes a large, square primary (transmitting) coil, within which are located four smaller secondary (receiving or sensing) coils. The four sensing coils are connected in parallel in such a way that three of them aid the primary-coil induction and one of them opposes it.

An oscillator having a frequency of 250 Hz switches a solid-state relay (see Figure 2) with a voltage of about 8 V. The relay generates a positive voltage pulse for the primary coils every 2 ms. For multiple-head operation, a sequential counter sends the pulses to each detector head in turn. The pulsed current in each primary coil induces a voltage in its secondary coils. This voltage is amplified, rectified, and compared with a reference dc voltage that corresponds to no metal in the detector field.

When metal is present in the detector field, the secondary-coil voltage deviates from the reference level. A departure of ±5 mV from the reference level causes the comparator to saturate at about 13 V output. The comparator output causes a driver to apply power to an indicator. In tests, the detector indicated a 3- by 3-in. (7.6- by 7.6-cm) box 17 in. (43 cm) from the detector head and a 7- by 12-in. (18- by 30-cm) box up to 24 in. (61 cm) from the detector head.

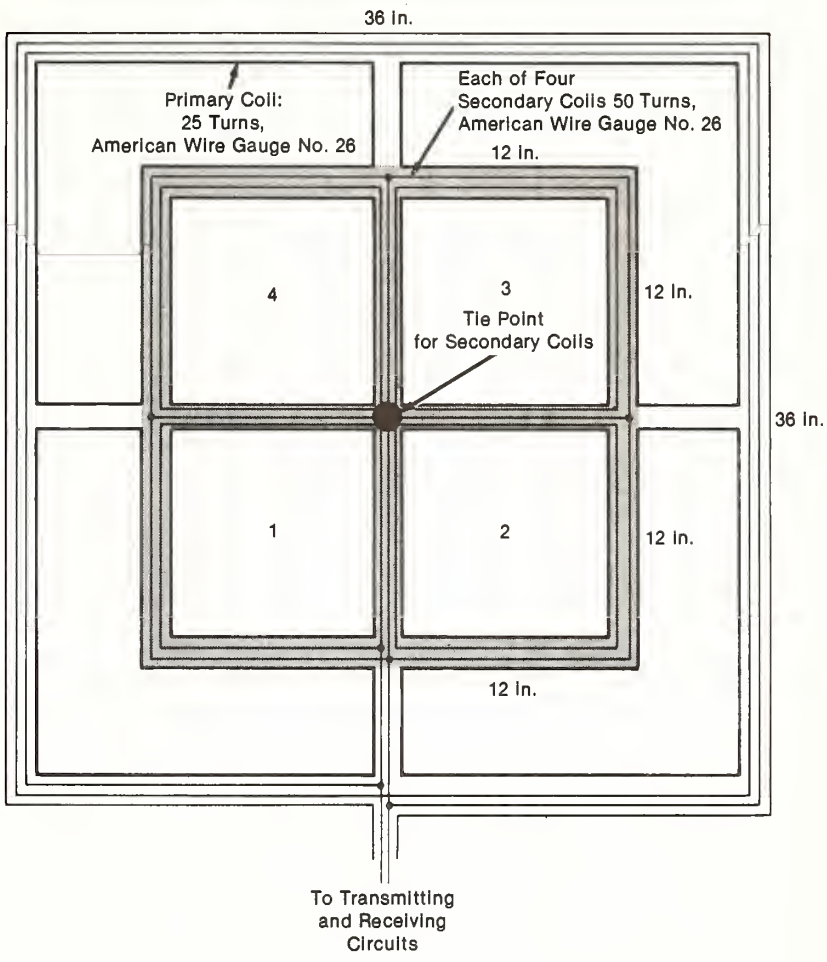


Figure 1. A **Detector Head** includes a large primary coil that induces current in the smaller secondary coils. An array of eight such heads enables a searcher to cover a large area relatively quickly.

This work was done by Edward S. Lesky, Alan M. Reid, Wilton E. Bushong, and Duane P. Dickey of **Kennedy Space Center.** *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center. Refer to KSC-11386/TN

John F. Kennedy Space Center
Technology Utilization Officer: Thomas M. Hammond
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Kennedy Space Center, FL 32899
(407) 867-3017
Patent Counsel: James O. Harrell
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Kennedy Space Center, FL 32899
(407) 867-2544

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

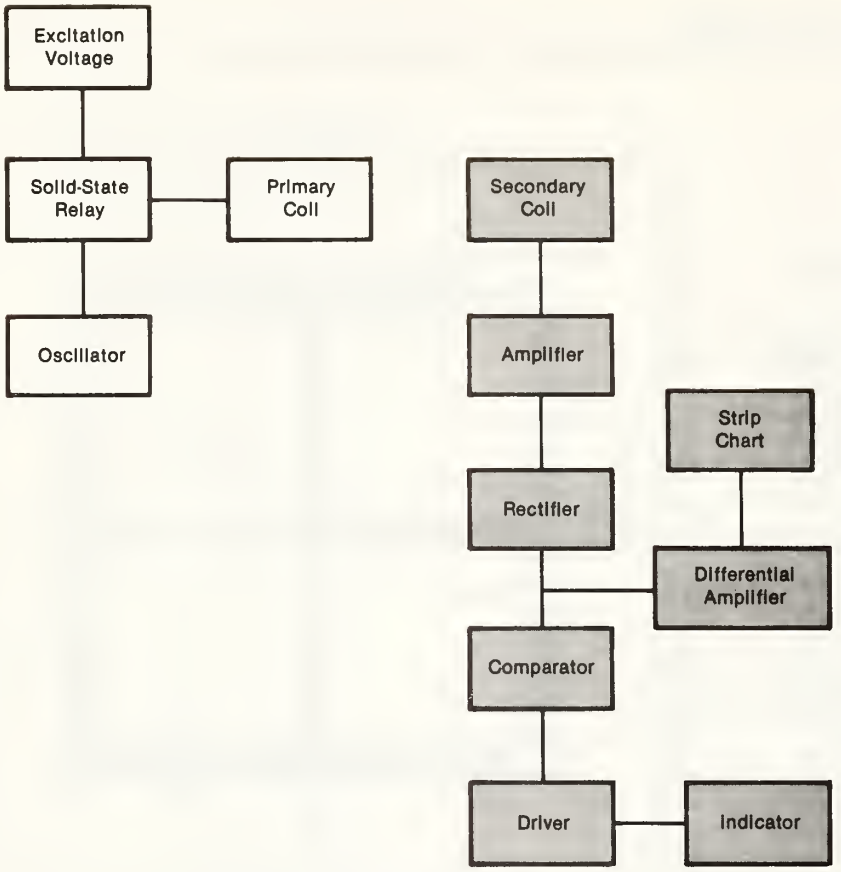

Figure 2. **Pulses Are Applied** to the primary coil, and the pulses induced in the secondary coils are measured to determine whether metal is present within the range of the detector head.

Environmental Science & Technology

0199 A Review of Methods for Remote Sensing of Atmospheric Emissions from Stationary Sources

0200 State-of-the-Art Landfill Design Available

United States
Environmental Protection
Agency

Environmental Monitoring
Systems Laboratory
Research Triangle Park, NC 27711

Research and Development

EPA

Project Summary

A Review of Methods for Remote Sensing of Atmospheric Emissions from Stationary Sources

This document provides a review of several remote monitoring systems that can be used to detect the presence of, or determine the concentration of, pollutant emissions in air. Remote sensing technologies were categorized as passive or active depending on the light source employed in the system. The description of techniques is organized into three sections: commercially available instruments, developing technologies, and potential developments. A brief discussion of practical considerations related to the use of remote sensing for air pollution emissions monitoring is also presented.

This Project Summary was developed by EPA's Environmental Monitoring Systems Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The surveillance of air pollutant source emissions is of concern to regulators, process operators, process engineers, air pollution control engineers, and air pollution researchers. The primary objective of this research was to provide a summary of remote sensing capabilities that have been used for, or are applicable to, air pollutant emissions monitoring. Many of these methods were identified.

The remote sensing technologies reviewed in this report are limited to those that rely on the interaction of a light source and some atmospheric property to detect the presence of an atmospheric constituent. Remote sensing technologies have been divided into passive systems and active systems. Passive systems use some natural light source; in active systems, a light source is included as a part of the instrument design.

This report presents an overview of remote sensing technologies and of the physical and chemical principles that are related to remote sensing. The specific remote sensing instruments identified during this effort are described. Practical considerations related to the application of methods for remote sensing of air pollutant emissions are presented.

Techniques and Principles

The basic physical principles behind many remote sensing techniques are discussed in general terms. As throughout the rest of this report, this section discusses passive and active techniques separately. Although passive techniques are often simpler, more mobile, and less expensive than active techniques, their use is often restricted to daylight hours and to good meteorological conditions.

Passive techniques may operate in either the emission mode or the adsorption mode of molecular spectroscopy. In the emission mode, the target gas (e.g., a heated plume) produces the radiation that is detected. In the absorption mode, an external but natural radiation source (e.g., sunlight) interacts with the target gas and is detected.

The most common light sources being used for active techniques are lasers. They are chosen for the high power that they have available at specific wavelengths of interest. However, with this advantage comes a potential eye hazard.

Summary of Remote Sensing Technologies

Both commercially available instruments and developing technologies are discussed in this section. Table 1 summarizes the methods and their developmental status. Such information as cost, weight, and power requirements are given for the commercially available instruments. In many cases, specification sheets for these instruments are

provided. There are more passive than active instruments commercially available. The relative cost of these two classes of instruments appears to be a determining factor in their availability.

Practical Considerations

Many applications of remote sensing technologies to source emissions monitoring have been discovered and several have become commercial ventures. In general, passive systems have been applied to routine monitoring of source emissions such as smokestack-type emissions, and active techniques have been applied more often to area or line sources involving potential accidental releases of explosive or hazardous materials. The companies that offer commercial pulsed laser measurement systems also offer van-mounted systems for lease at considerably less cost than the purchase price.

Remote sensing of air pollutants can be applied to a significant list of pollutant species. Advancements and research can provide capabilities for the measurement of many more air pollutants. Technologies exist that can be used to measure almost any air pollutant by remote sensing principles. The investment of labor and money to develop, build, and test a system can often be significant and even prohibitive; thus, careful planning is required for projects concerned with emissions monitoring by remote sensing. In many instances, the benefits would justify the potential costs, but every application should be considered individually.

There are limitations to passive remote sensing systems that rely on natural radiation. One is the dependence on favorable meteorological conditions. There are wide variations of the light source intensities in different locations, during different seasons, and during periods of the same day at the same location. Compensation for the variations often requires additional steps in the signal processing and data reduction, and short-term variations still contribute to error. Another limitation of passive remote sensors is the inability to determine the amount of emissions as a function of distance from the detector. Thus, range-resolved spatial mapping of the gas usually cannot be obtained. Rather, the measurement is the integral concentration of emissions along the entire line of sight. The quantity measured is optical depth, the product of a concentration and a pathlength. These limitations do not preclude the use of passive devices for remote sensing of source emissions. Passive sensors are generally simpler, more convenient, easier to operate, and easier to maintain than active sensors. They are also usually considerably less expensive than active sensors.

Active systems have severe limitations as well. They are often cumbersome, they sometimes require special power supplies, and optics alignment can involve regular maintenance and attention. Pulsed laser systems, used to obtain range-resolved measurements, require sophisticated signal-processing electronics and significant data storage capacity. The operation of the system, data handling tasks, data interpretation, and routine system maintenance often require a skilled technician trained for the task.

Advantages of active techniques are related to extent of coverage either spatially or temporally. The spatial coverage offered by either computer-controlled or mobile, mounted systems is obvious. A sweep of an entire chemical complex can be accomplished in several minutes by using a computer-controlled laser-based system. A mobile system mounted on a truck or a van can define the extent and characteristics of a widely dispersed power plant plume in a short time.

The temporal coverage provided by continuous long-path systems makes them well-suited for perimeter monitoring and pipeline surveillance in cases where hazardous materials can be released inadvertently. Long-lasting light sources and simple electronics that locus on alarm level detection make these systems capable of continuous, unattended operation for long periods of time. Often, lasers are not required or even desired for this type of application, and the simplicity that can be tolerated brings the cost down to levels competitive with passive remote sensing systems.

Table 1 *Remote Sensing Methods for Source Emissions Measurements and their Development Status*

Method Class	Method	Developmental Status
Passive	Radiometers, heterodyne	Developing technology
	Radiometers, imaging	Commercially available
	Spectrometers	Not applicable
	Interferometers	Commercially available
	Correlation spectrometers, dispersive	Commercially available
	Correlation spectrometers, nondispersive	Commercially available
Active	Long-path infrared absorption	Commercially available
	Lidars, atmospheric (Mie) backscatter	Commercially available
	Lidars, differential absorption	Commercially available
	Lidars, fluorescence	Undeveloped
	Lidars, Raman backscatter	Commercially available
	Lidars, Doppler	Developing technology
	Lidars, wedge absorption	Developing technology
	Gas imaging	Developing technology

Mark L. Saeger, Cynthia K. Sokol, Susan J. Coffey, and Robert S. Wright are with Research Triangle Institute, Research Triangle Park, NC 27709. William E. Farthing and Kim Baughman are with Southern Research Institute, Birmingham, AL 55305.
Roosevelt Rollins is the EPA Project Officer (see below).
The complete report, entitled "A Review of Methods for Remote Sensing of Atmospheric Emissions from Stationary Sources," (Order No. PB 88-190 483/AS; Cost: $14.95, subject to change) will be available only from
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Environmental Monitoring Systems Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

NAVY
Domestic Technology Transfer Fact Sheet

State-of-the-Art Landfill Design Available

All landfill liners, no matter how well they are constructed or from what material, are pervious to some degree. Even the best geomembranes have a limited lifetime. Intragradient Design Concept is most effective in areas with low permeability geologic strata and a relatively high groundwater table.

An intragradient landfill is constructed to induce groundwater flow into the landfill by situating the facility beneath the zone of saturation. By keeping the saturation level within the landfill below that of the exterior, the hydraulic gradient of the landfill is the reverse of the usual landfill design; and groundwater flow is into the intragradient landfill structure. Liners used in this design concept need to be of sufficiently low permeability to divert most of the groundwater around the structure, thus maintaining the reverse hydraulic gradient.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 130902/TN

Manufacturing, Machinery, & Tools

0201 Composite Duct Enters Production—Outperforms Titanium

0202 Integrated Metrology System

0203 Product Definition Data Interface

0204 Angular-Momentum-Compensating Servomechanism—This nonlinear servomechanism prevents reaction torques from disturbing the supporting structure.

0205 Arc Plasma Gun with Coaxial Powder Feed—Powder is injected directly through the cathode into the plasma jet. (Licensing Opportunity)

0206 Dimpling Tools Would form Fastener Neatly—A cup washer would be deformed to hold a screwhead. (Licensing Opportunity)

0207 Laser Micromachining in a Reactive Atmosphere—Chemical reactions remove machining waste.

0208 Gas-Diverting Cup for Welding at an Angle—An attachment makes automatic arc welders more versatile.

0209 Mapping Redistribution of Metal in Welds—Displacements are detected with radioactive tracers.

0210 Pyrotechnic Tubing Connector—A tool would form a mechanical seal at a joint without levers or hydraulic apparatus.

0211 Repair of Graphic EDM Electrodes—These electrodes can be repaired by a silver-filled, epoxy-based adhesive.

0212 Shaping Plastic Covers Quickly and Cheaply—A cover of complicated shape can be made in only half an hour.

0213 Sine-Bar Attachment for Machine Tools—Cutting angles can be set more easily. (Licensing Opportunity)

0214 Starting VPPA Welds Without Pilot Holes—Welding current is turned on gradually. (Licensing Opportunity)

NAVY Manufacturing Technology Program

Composite Duct Enters Production - Outperforms Titanium

Beginning in 1989, F404 engines for the F/A-18 aircraft will be delivered to the Navy with outer compressor ducts fabricated from graphite composite material. The new ducts will not be subject to foreign-object-damage-induced ignition as are the chemically milled titanium ducts they are replacing, and they will be at least 20% lighter and 30% less expensive than fireproof-lined titanium ducts. They will also eliminate the need for 220 pounds of titanium, a strategic material, per engine.

The effort required to successfully apply composite material technology to turbine engine structures began over ten years ago with a research and development program sponsored by the National Aeronautics and Space Administrations's Lewis Research Center and the Naval Air Systems Command in cooperation with the General Electric Aircraft Engine Business group. Exploratory development by NASA-Lewis and GE from 1974 through 1977 resulted in the fabrication and engine testing of large cowling components made of high temperature graphite and PMR-15 polymer resin. The test results led to a joint NAVAIR/NASA/GE component development program in 1978. A one-piece subscaled F404 duct was the first component to be tested in 1980. This scaled duct was followed by a full-size two-piece duct fabricated with titanium flanges, and finally an all-composite duct was built and engine-tested in late 1981. A NAVAIR-sponsored manufacturing technology project (number A0725) with GE was started in 1982 and ultimately resulted in the establishment of an efficient, cost effective method for producing the all-composite ducts. Six F404 ducts were produced and passed all component, ground, engine, and F/A-18 flight qualification tests.

Although the manufacturing technology effort was completed in 1984 and the target introduction date for production implementation was 1985, a significant event occurred which unexpectedly put a damper on this technically successful project. The roughly $9,000 per unit cost advantage initially expected to be realized by switching from titanium to all-composite ducts essentially disappeared as the titanium duct suppliers reduced their prices to remain competitive and retain their place in the market. Production implementation, one of the criteria for success of any manufacturing technology project, appeared to be unachievable. The fact that the savings resulting from the reduced cost of the titanium ducts were directly attributable to the project tended to be overlooked. It was not until last year that FOD-induced titanium duct ignition became identified as a safety-of-flight issue and prompted renewed interest in the potential of the composite duct. With production implementation, it now can be said that this NAVAIR-sponsored manufacturing technology project is truly a total success, with replication likely in engine components for the A-12 and other advanced aircraft.

For further information, contact:
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AV 624-2174

U.S. Army Fact Sheet

Integrated Metrology System

A plan has been formulated which provides practical guidelines as to how metrology can be integrated into a current production operation. In addition, it assists the manufacturer in future dimensional measurement system developmental activities. The plan includes a Composite Factory Practices Model which defines the Integrated Metrology System in terms of a set of organized models. This methodology will provide an organized systematic approach in selecting, justifying, and integrating appropriate inspection technologies into production operations.

FOR ADDITIONAL INFORMATION: Additional information can be obtained by contacting Mr. W. Roll, AMXIB-PA, Production Engineering Division, U.S. Army Industrial Engineering Activity, Rock Island, IL 61299-7260; (309) 782-5617.

U.S. Army Fact Sheet

Product Definition Data Interface

The results of McDonnell Aircraft Company's (MCAIR) work on the Product Definition Data Interface (PDDI) Extension was recently presented at the Joint Geometric Modeling Applications Interface Program (GMAP) and PDDI Extension Industry Review Board (IRB). Pratt & Whitney (PW) also presented the status of GMAP, a project that builds on the results of PDDI. In addition, PDDI and GMAP support of the Product Data Exchange Specification (PDES) community was presented.

The PDDI program, which was initiated in 1982, was targeted toward the functional replacement of engineering blueprints. The project examined digital part definition with major emphasis on the definition of long range manufacturing needs and demonstrated a prototype product definition data exchange to meet these needs. The focus was on a "complete" product definition system for parts designed by engineering for direct transfer to manufacturing. The Air Force awarded PW the GMAP project on 1 August 1985. GMAP builds upon the results of PDDI supporting the exchange of data over the entire life cycle and by representing a greater range of mechanical parts. This life cycle is defined to include engineering, manufacturing, inspection, and logistics support. In December 1986, while GMAP was in progress, the Air Force awarded MCAIR an extension to the PDDI contract. The extension program focused on extending the capabilities of PDDI concept to industry and demonstrating the transfer of "complete" product definition data between customer, contractor and sub-contractor using dissimilar computer-aided design (CAD) systems.

There has been close coordination between the PDDI/GMAP and PDES communities. PDDI and GMAP efforts support direct applications to a limited range of parts while PDES applications are more generic. These test-bed projects (PDDI and GMAP) are supporting the PDES community by providing participation in committee meetings and providing expertise in product definition data. PDES, PDDI and GMAP all support the overall Computer-Aided Acquisition and Logistic Support (CALS) effort.

FOR ADDITIONAL INFORMATION: For additional information contact Mr. Mark Seelhammer, U.S. Army Industrial Engineering Activity, Rock Island, IL 61299-7260; (309) 782-3682.

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Angular-Momentum-Compensating Servomechanism

This nonlinear servomechanism prevents reaction torques from disturbing the supporting structure.

A servomechanism for rotating an instrumentation platform isolates the supporting vehicle or stationary platform from reaction torques produced by the rotations. The servo thus prevents the aiming of an instrument from disturbing the vehicle or other instrument platforms.

The servo includes a reaction wheel that provides a compensating torque to oppose the reaction torque. It uses a stepping motor instead of a continuously running motor to avoid the tendency to stick, which plagues linear motors at low speeds. In addition, it uses a set of reduction gears to connect the motor to the load instead of connecting it directly and thus provides both ample torque margin and more precise aiming.

The shaft of the motor, the reaction wheel, and gear 1 of the gear train rotate counter to the platform (see figure). If the angular momentum stored in these rotating elements precisely matches that stored in gear 2, the output shaft, the platform, and the load, the system forms a closed, reactionless unit that transmits no torque disturbances to the structure on which it is mounted.

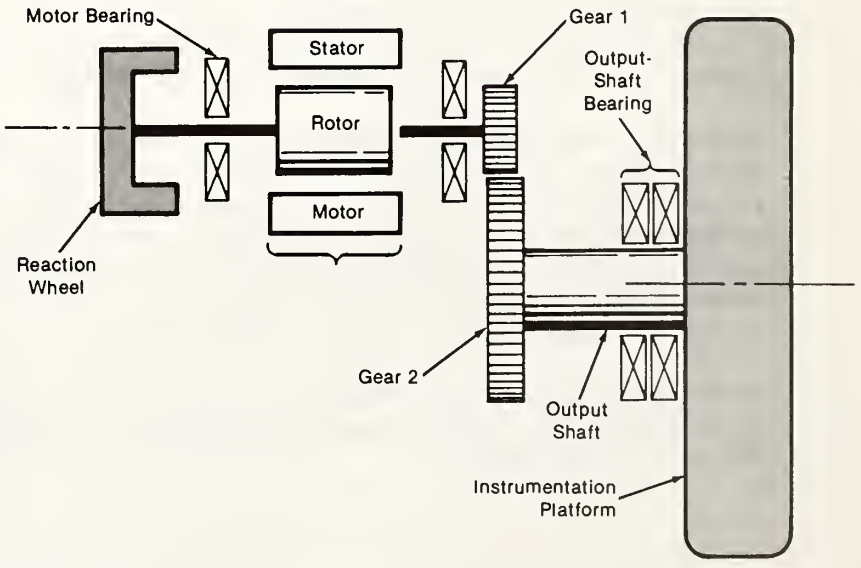
The desired perfect balance can be upset during angular acceleration if there is backlash between gears 1 and 2. Therefore, a high-quality gear train must be used — one having little or no backlash. Moreover, motor cogging — variations in torque and speed resulting from variations in magnetic flux as rotor poles move past stator poles — can act in concert with backlash to inhibit or prevent the precise matching of angular momentum and to cause overshoots. The accelerations from cogging are not transmitted exactly to the platform but are taken up partly by the shaft and gear-tooth compliance. The stepping motor, with its short, precise movements and high damping, reduces the effects of cogging.

The natural 1.8° step of the stepping motor is divided into microsteps. Using a sine/cosine microstepping procedure, logic circuitry divides the motor current into 64 discrete levels that are applied as pulses to both windings of the two-phase motor. With each pulse, the rotor takes a step of 0.028°.

The stepping motor drives a 100:1 gear train, producing a rotation of 1.0125 seconds of arc with every pulse. Because the system operates in discrete steps, it reaches the final position without overshooting or undershooting, within the resolution of 1 microstep. Thus, unlike a linear servo, this nonlinear system attains high angular resolution without sacrificing slowing speed.

Instead of conventional spur gears, the gear train includes a circular spline, a wave generator, and a flexible spline. This system reduces backlash and tooth-mesh error and carries higher loads than does a spur-gear train. The circular and flexible splines engage on the pitch circle at two diametrically opposed points. If the errors of both tooth meshes are equal and of opposite sign, they cancel. Only if they are equal and of the same sign do they equal the mesh error of a spur-gear train. In practice, 10 or more spline teeth are engaged at each mesh point, and this exerts an additional averaging effect on the errors in the placement and shapes of the spline teeth.

This work was done by Carl A. Marchetto of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-17173/TN*



Rotating Oppositely to the instrument platform, the reaction wheel, motor, and gear 1 have angular momentum equal and opposite to that of gear 2, the output shaft, and the platform. The external torque reaction to the rotation of the platform is thus canceled. Although spur gears appear in this schematic diagram, the gear train is made of spline gears.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief

National Aeronautics and Space Administration

Lewis Research Center, Cleveland, Ohio

Licensing Opportunity

Arc Plasma Gun With Coaxial Powder Feed

Powder is injected directly through the cathode into the plasma jet.

A redesigned plasma gun provides improved metallic and ceramic coatings. In a present arc plasma gun, the particles to be sprayed are injected orthogonally to the plasma jets either outside the nozzles or internally through circularly distributed holes in the nozzles (see Figure 1). With this method of injection, only some of the particles penetrate to the central region of the jet, and a significant part of the injected particles becomes entrained in the external, relatively cooler region of the plasma jet. This causes the injected particles to acquire a spectrum of velocities and temperatures, and some of them are either partially melted or totally unmelted.

To provide a more-uniform temperature and velocity distribution of the particles in the improved plasma gun, the particles are injected directly through a coaxial bore in the cathode into the central region of the plasma jet (see Figure 2). In this manner, the particles are introduced into the hotter and faster region of the plasma jet.

In addition, the coaxial injection increases the time of residence of the particles in the plasma jet and eliminates the cooling effect of the feeder gas on the plasma. In this case, the feeder gas becomes a part of the arc gas. Another feature of the new design is the cooling of the cathode by the feeder gas. To optimize the performance of the plasma gun for various powder and arc gases, the position of the cathode can be adjusted.

This work was done by Isidor Zaplatynsky of **Lewis Research Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center [see page 18]. Refer to LEW-14539/TN

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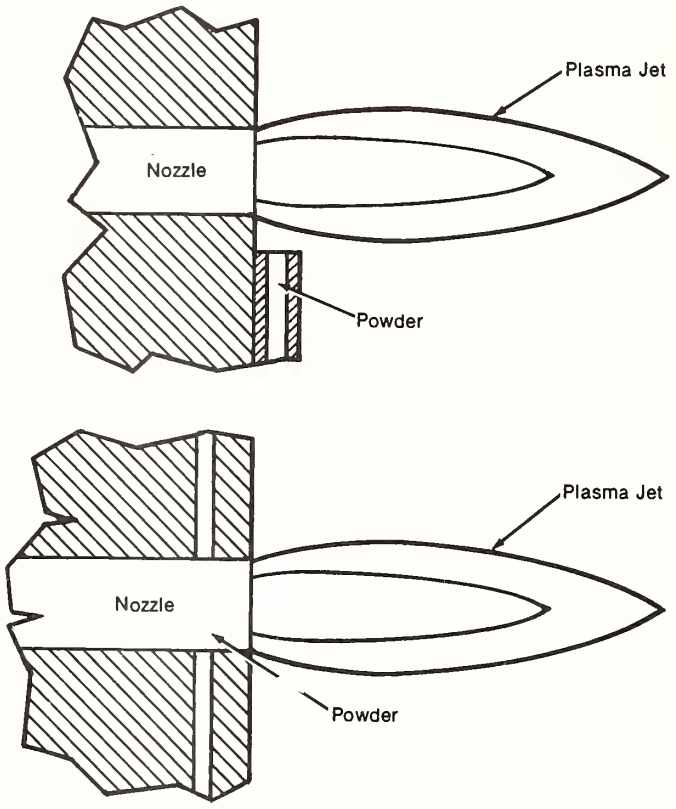

Figure 1. **Powder Is Injected From the Side** in plasma guns of conventional design.

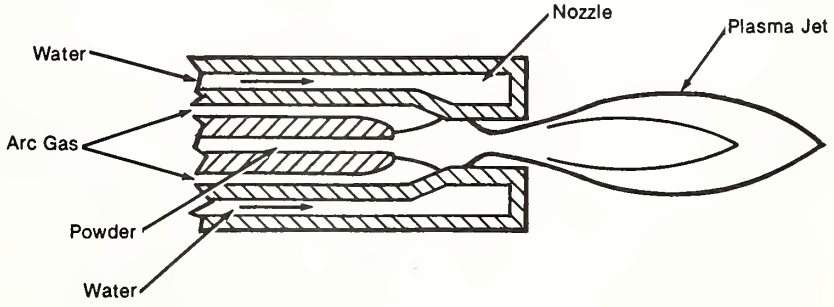

Figure 2. **Powder Is Injected Along The Axis** of the improved plasma gun.

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Dimpling Tools Would Form Fastener Neatly

A cup washer would be deformed to hold a screwhead.

A proposed set of tools would neatly dimple a cup washer to prevent a screw from turning in its mounting hole. Two dimples are required: one leaning outward to grip a recess in the mounting hole and one leaning inward to grip a recess in the screwhead. The tools would not cause the cracks and tears that are often created when cup washers are dimpled by hammers and center punches. The tools would substitute a die-forming process for the hammer-and-center-punch process. The die-forming process would require less skill and would give results of greater quality and consistency.

The inward-leaning dimple would be formed first. As shown in Figure 1, the screw would be mounted on a plate and oriented with its recess facing a staking die. The screw and cup washer would be squeezed between the staking die and the die shoe, bending a portion of the cup washer into the recess in the screwhead.

The screw and cup washer would then be inserted in the mounting hole and oriented so that the first dimple faces away from the mounting-hole recess to be engaged. The forming tool in Figure 2 would be aligned approximately with the recess to be engaged, then forced between the cup washer and the screwhead to bend part of the cup washer outward. The shoulder on the holder of the forming tool would prevent insertion to an excessive depth.

This work was done by Michael D. Roberts and Donald R. Hendrickson of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center Refer to MFS-29306/TN

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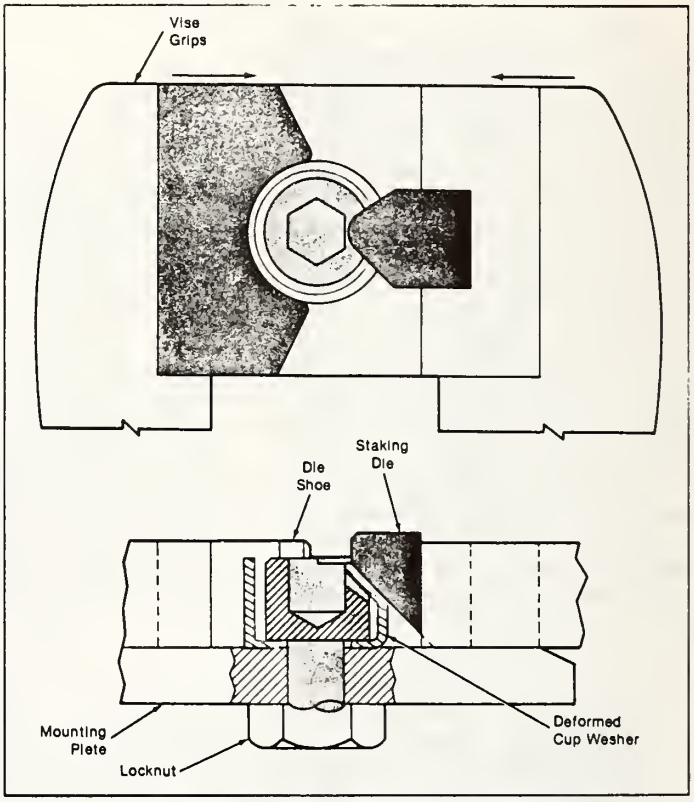

Figure 1. A **Staking Die** would form a dimple in the cup washer, causing the washer to grip the head of the screw.

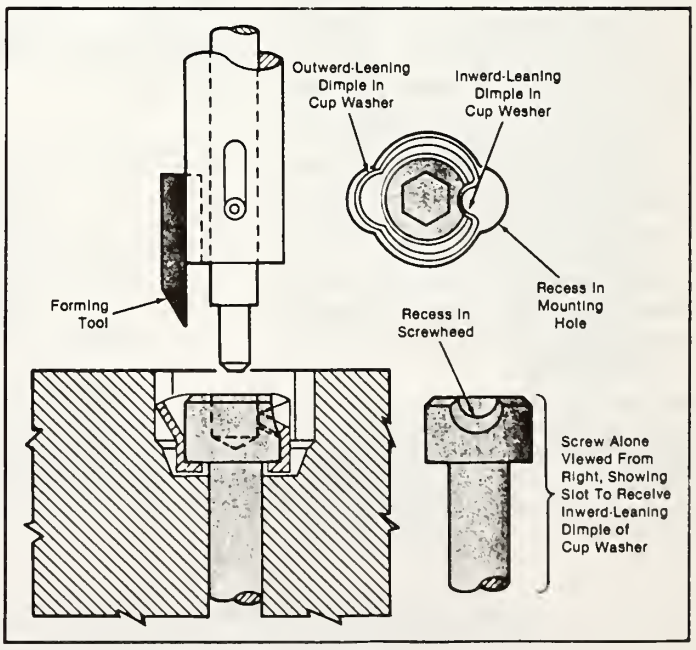
Outwerd-Leening Dimple In Cup Washer
Inwerd-Leaning Dimple In Cup Wesher
Forming Tool
Recess In Screwheed
Recess In Mounting Hole
Screw Alone Vlewed From Right, Showing Slot To Receive Inwerd-Leaning Dimple of Cup Washer

Figure 2. A **Forming Tool** would create another dimple in the cup washer, causing the washer to grip one of the recesses in the mounting hole. The screw would then be restrained against turning.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Laser Micromachining in a Reactive Atmosphere

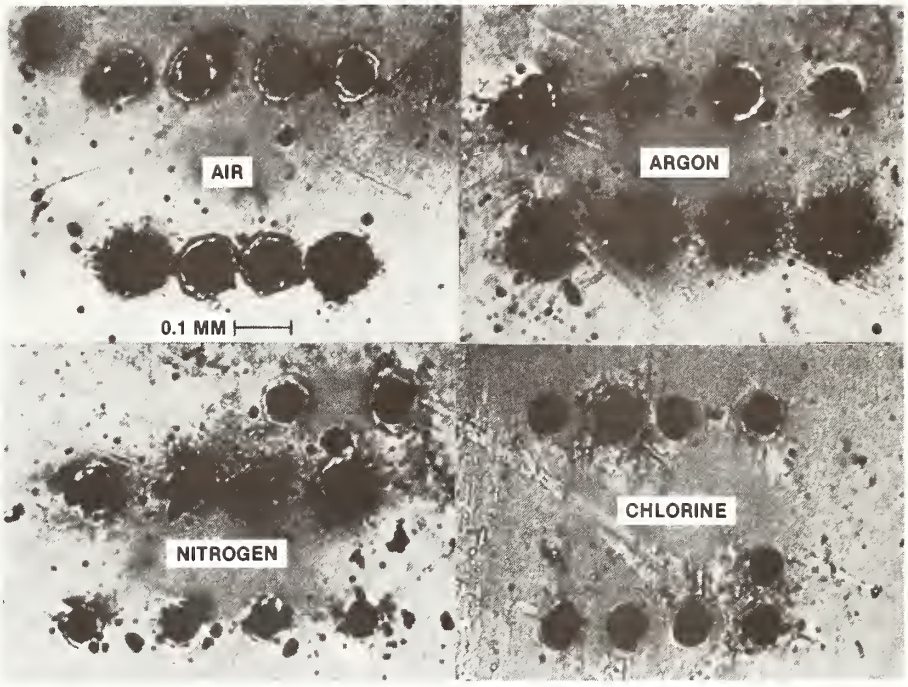
Chemical reactions remove machining waste.

The drilling of deep holes in silicon by a laser beam is aided by conducting the operation in a reactive atmosphere. The atmosphere reacts with material ejected from the hole and converts the material to a gas that flows away from the work area. The hole is cleaner and more sharply defined, and debris do not spatter the surface of the work.

When holes are drilled in a silicon chip by a laser beam in air or in an inert atmosphere, solid debris collect around the holes. However, if the procedure is done in chlorine gas, the silicon vapor and droplets leaving the hole combine with the chlorine to form silicon tetrachloride gas.

In a demonstration, holes 0.030 and 0.003 in. (0.76 and 0.076 mm) in diameter were drilled in silicon wafers in various atmospheres. A portable manifold controlled the flow of air, oxygen, nitrogen, argon, or chlorine in a microscope-stage reaction chamber. A ruby-laser beam entered the chamber through a thin glass window.

The holes drilled in a chlorine atmosphere were more regular than those drilled in air, nitrogen, or argon and were completely free of debris (see figure). Drilling in oxygen converted the ejected silicon to fluffy white silica debris that interfered with visibility but probably did not damage the silica layer on the wafer surface.



Spattered Silicon surrounds laser-drilled holes, except those made in a chlorine atmosphere. The reaction of silicon and chlorine not only eliminates debris but also makes the holes more nearly round.

This work was done by Paul J. Shlichta of Caltech for **NASA's Jet Propulsion Laboratory** *and George Zahaykevich of Advanced Laser Systems, Inc.*

NPO-16587/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

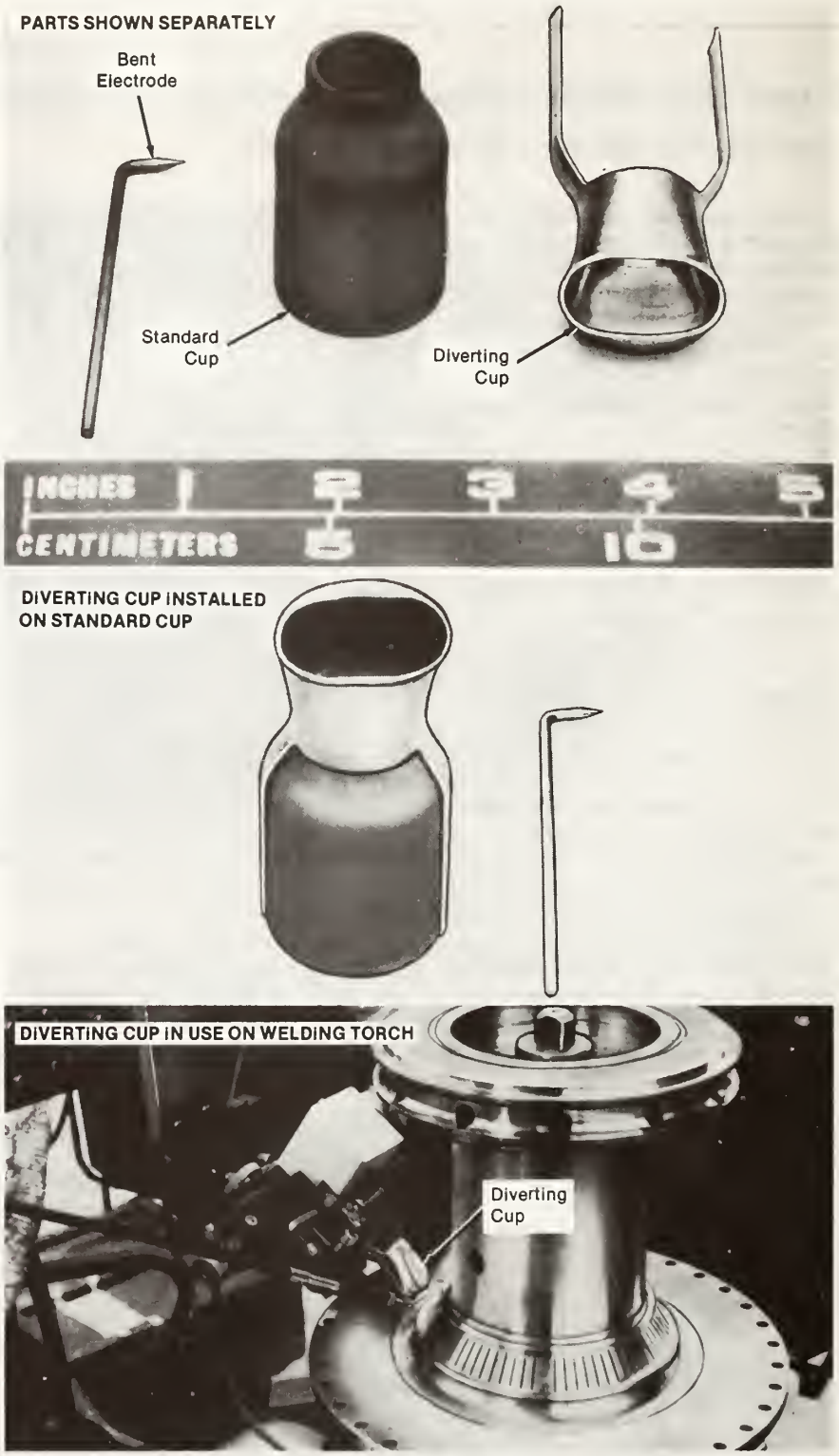
Gas-Diverting Cup for Welding at an Angle

An attachment makes automatic arc welders more versatile.

A simple add-on cup for a gas/tungsten arc-welding torch makes it possible to weld in previously inaccessible places. The cup, made of stainless steel, is slipped over a welding torch equipped with a standard No. 10 cup. The add-on cup changes the angle of the gas flow, diverting it 60° away from its usual direction. The tungsten electrode is also bent 60° a short distance from its tip (see figure).

With the add-on cup and the bent electrode, an automatic welding machine can reach joints between protrusions that would interfere with the movement of a straight electrode and gas stream.

This work was done by G. E. Dyer of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29206/TN



The **Stainless-Steel Diverting Cup** shown at the right in the top photograph slips over the standard torch cup as shown in the middle photograph, and the bent electrode is inserted in the torch. The assembly can reach weld joints that are inaccessible to a straight welding torch, as shown in the bottom photograph.

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Mapping Redistribution of Metal in Welds

Displacements are detected with radioactive tracers.

A radioactive-tracer technique can be applied to map the redistribution of metal caused by a welding process. This technique can be used to verify the predictions of computer codes for the dynamics of fluids in weld pools. These codes are important because they contribute to understanding of the dynamics and thereby may help to provide better welds that have lower residual stresses. Before the advent of the new technique, there was no way to verify the predictions of the codes after the completion of welds.

Before welding, the surfaces of the parts to be welded are irradiated by particle-beam generators to make them slightly radioactive to a specified depth in the range of 0.001 to 0.100 in. (0.025 to 2.5 mm). The total radioactivity can be less than 10 μCi — less than the level that requires licensing.

During welding, the radioactive material from the surface layer is churned with the other molten material. Eventually, the radioactive and nonradioactive components solidify in new positions. The new distribution of radioactivity can be imaged by gamma-ray detectors or photographic film. For finer three-dimensional detail, the weld region can be sliced into thin layers prior to imaging.

This work was done by Sarkis Barkhoudarian of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29487/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Pyrotechnic Tubing Connector

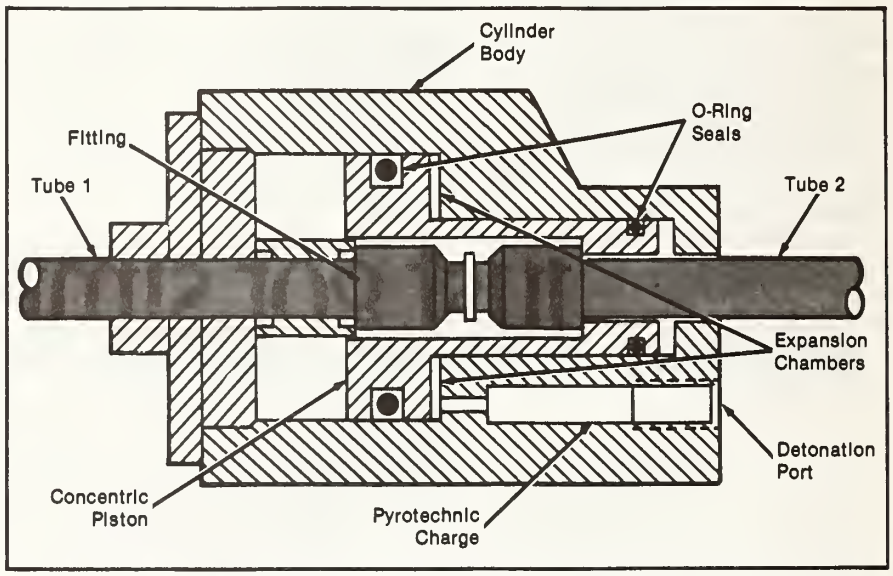
A tool would form a mechanical seal at a joint without levers or hydraulic apparatus.

A proposed tool intended for use in outer space could be used on Earth by heavily garbed workers to join tubing in difficult environments. The tool, called Pyrotool, would be used with Lokring (or equivalent) fittings. Ordinarily, Lokring (or equivalent) fittings are slipped over the ends of the tubes to be joined and are compressed by a lever or by hydraulic pressure so that they form a leaktight connection.

The Pyrotool (see figure) would employ a pyrotechnic charge to compress the fittings. It would include a piston and cylinder containing the fittings and would be preattached to the end of a tube section. The user would insert the mating tube in the tool and fitting and would detonate the charge by mechanical or electrical means. The burning charge would generate pressure on the piston face, driving the piston toward the mating tube so that it compresses the fitting, thereby joining the tube ends.

The joining process would be completely contained and would create no debris. Once used, the tool would remain on the joined tubes.

This work was done by Thomas J. Graves and Robert A. Yang of **Johnson Space Center**. *MSC-21262/TN*



The **Piston Slides in the Cylinder** when pushed by gas from a detonating pyrotechnic charge. The impulse of the piston compresses the fittings, sealing them around the butting ends of the tubes.

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Repair of Graphite EDM Electrodes

These electrodes can be repaired by a silver-filled, epoxy-based adhesive.

The cost of electrical-discharge machining (EDM) can be reduced by use of an electrically conductive adhesive to repair worn or damaged sections of the graphite electrodes. Previously, damaged electrodes had to be replaced, because they were made without extra stock for remachining.

To provide extra material for remachining, pieces of graphite can be bonded to a damaged electrode with Eccobond (or equivalent) silver-filled, epoxy-based adhesive. Because this adhesive is electrically conductive, the electrical conductivity of the electrode is not impaired. Once repaired, the electrode is machined to the designed configuration and returned to service.

This work was done by Glenn Burow of Rockwell International Corp. for **Marshall Space Flight Center**. *MFS-29138/TN*

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Shaping Plastic Covers Quickly and Cheaply

A cover of complicated shape can be made in only half an hour.

A fixture enables the thermal forming of custom-contoured plastic covers in only half an hour. Previously, two workers needed 12 hours to form such a cover by hand. The fixture is inexpensive and compact.

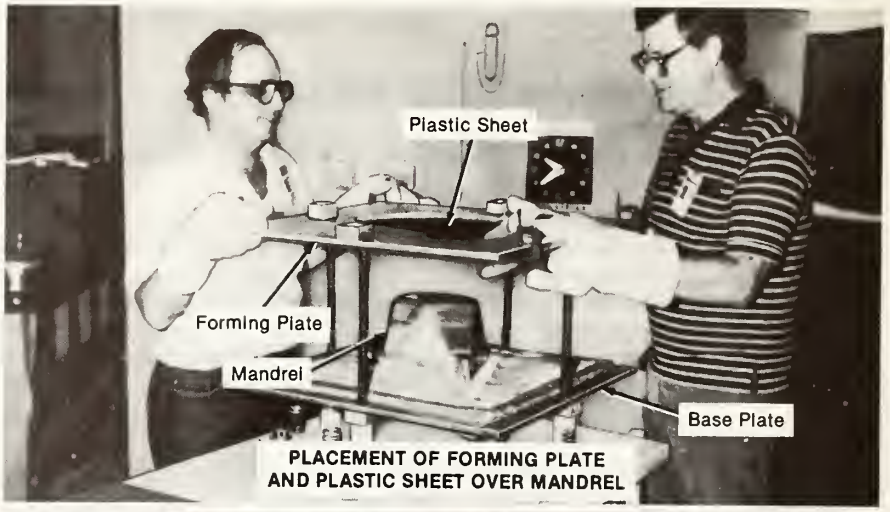
The fixture (see figure) includes an aluminum baseplate and an aluminum forming plate with an opening cut out to match the cover outline. The pair of plates is mounted on a set of four rods, one rod at each corner of the plates. A spring on each rod pushes the forming plate toward the baseplate.

A wood mandrel is built to match the internal dimensions of the cover. The mandrel is secured to the baseplate and a sheet of plastic is placed on the top of it. The forming plate is placed on the plastic sheet, which may be of a material like acrylonitrile/butadiene/styrene (ABS). The forming plate is spring-loaded against the baseplate.

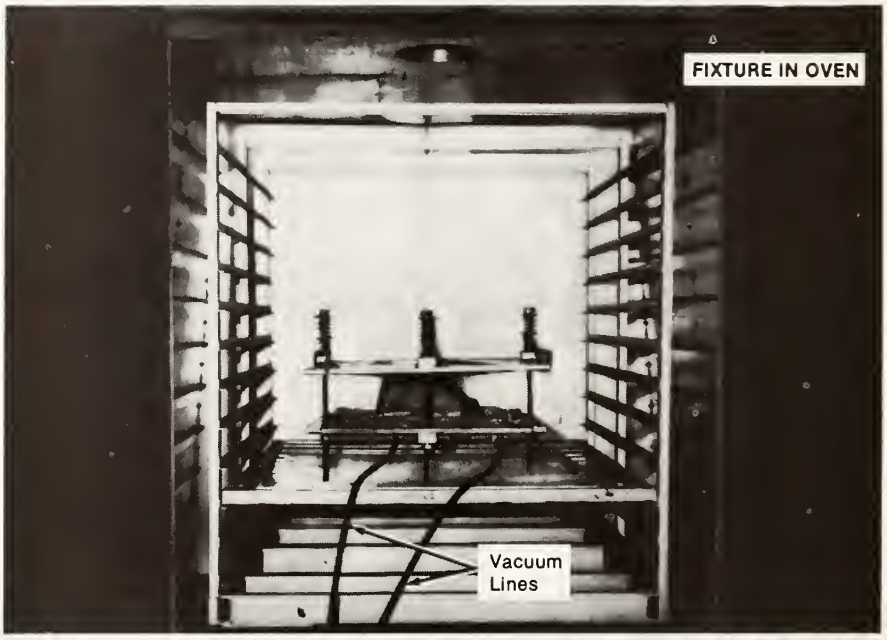
The fixture and its contents are heated in an oven to soften the plastic, allowing it to deform to the contour of the mandrel. Once the plastic sheet meets and seals against the baseplate due to spring pressure, a vacuum is applied from below to finish the forming operation by forcing the plastic tightly against the mandrel.

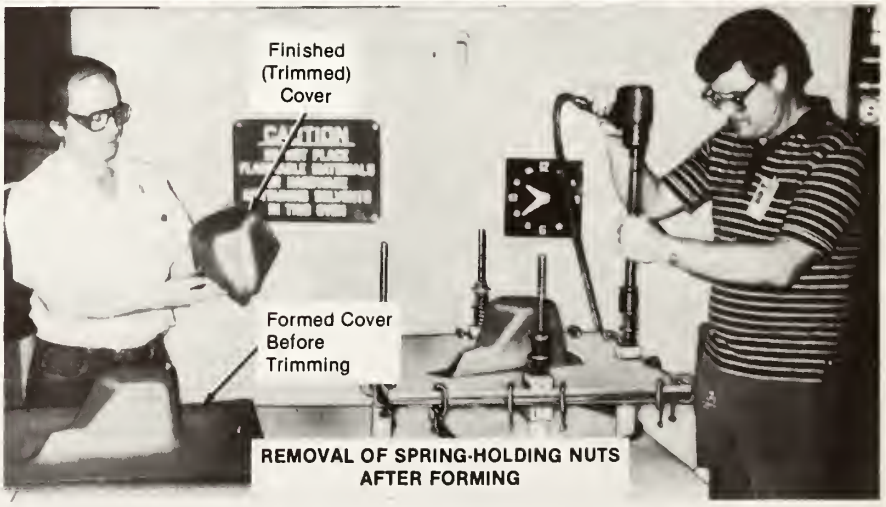
Because the mandrel tends to deform in the heat of the oven, it is not used repeatedly. Instead, a new mandrel is made by pouring plaster into the first plastic part made on the wooden mandrel.

This work was done by I. Gurman and D. Muckey of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29188/TN



PLACEMENT OF FORMING PLATE AND PLASTIC SHEET OVER MANDREL





REMOVAL OF SPRING-HOLDING NUTS AFTER FORMING

In the **Assembled Cover-Forming Fixture**, the spring-loaded forming plate presses the plastic sheet toward the baseplate. Finished covers are stacked at the left side of the table.

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Sine-Bar Attachment for Machine Tools

Cutting angles can be set more easily.

A sine-bar attachment for collets, spindles, and chucks helps machinists set up quickly for precise angular cuts that require greater precision than provided by the graduations on the machine tools. The machinist uses the attachment to index the head or carriage of a milling machine or lathe relative to the table or turning axis of the tool. The attachment is accurate to 1 minute of arc, more or less, depending on the length of the sine bar and the precision of the gauge blocks in the setup.

A reference bar is attached by screws to one of three sides of a collet adapter (see Figure 1), depending on the job and the angle. The sine bar is loosely positioned on the collet adapter by a locking nut and bolt extending through one of four slots in the adapter and a hole in the middle of the sine bar. Gauge blocks are inserted at one end of the sine bar to provide the required height for the angle according to the formula: length of sine bar × sine of desired angle = height of gauge blocks. The locking nut is tightened so that the sine bar rests securely on the reference bar and gauge blocks.

Next, the assembly is securely chucked in the collet (or chuck or spindle) of the machine. The diameter "A" of the collet adapter is checked for concentricity by a dial indicator. The collet, with its sine-bar attachment, is indexed so that it is either perpendicular or parallel to the direction of travel of the table. A dial indicator is then used to adjust the machine head or the table to the desired angle (see Figure 2); when the adjustment is correct, the indicator will read zero change as it traverses the sine bar. The assembly is then removed, and the machine is used to cut a part to the desired angle.

The attachment can be installed quickly and easily on almost any type of lathe or mill. It requires no special clamps or fixtures, and it eliminates many trial-and-error measurements. It is more stable than improvised setups and cannot be jarred out of position readily.

The usefulness of the attachment can be increased further by adding a fourth

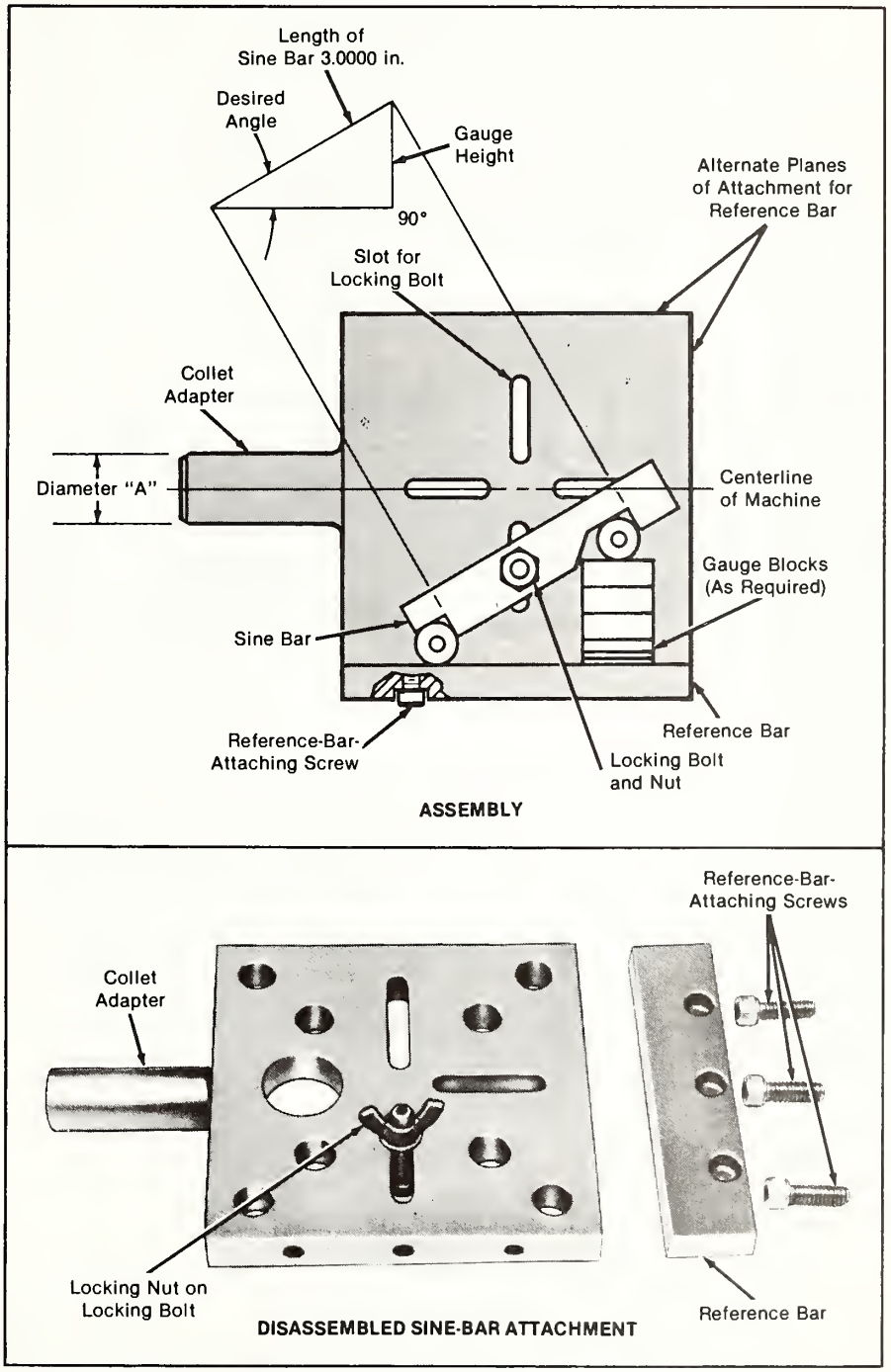

Figure 1. The **Sine-Bar Attachment** can hold a sine bar at a desired angle with respect to any of three reference planes.

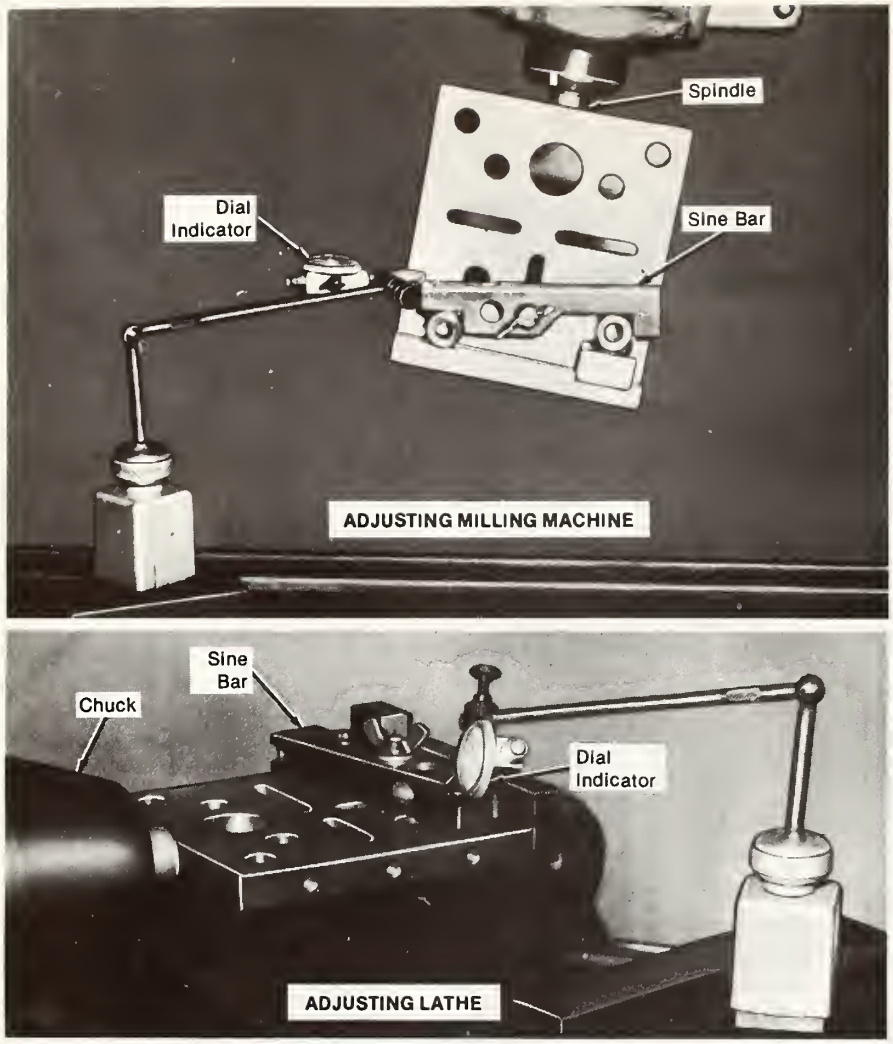

Figure 2. A **Milling Machine and a Lathe** are adjusted to precise angles with the help of the sine-bar attachment.

reference-bar-mounting edge perpendicular to the three edges already available. Compound-angle setups could then be made without reindexing the collet adapter.

This work was done by Franklin D. Mann of **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center Refer to MFS-28253/TN

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Starting VPPA Welds Without Pilot Holes

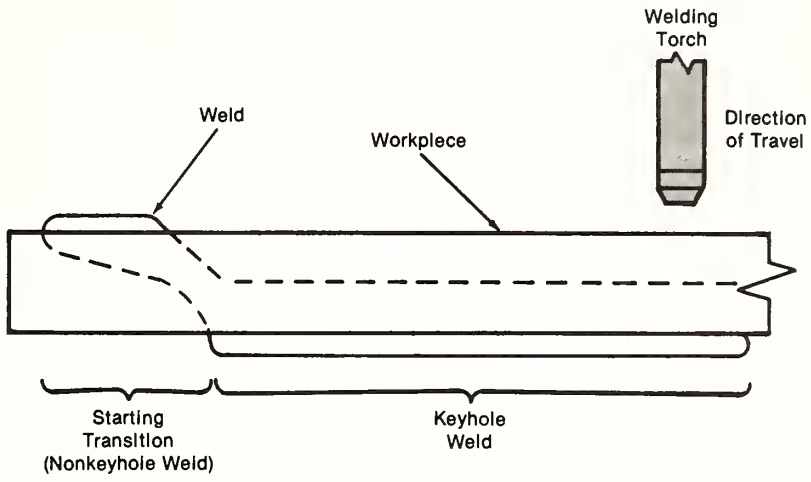
Welding current is turned on gradually.

Variable-polarity plasma-arc (VPPA) "keyhole" welds can be initiated without pilot holes or starting tabs, by use of a simple gradual-turn-on technique. Although pilot holes have typically yielded 80-percent repeatability, tests in the laboratory and in production show that the gradual-turn-on technique is 100 percent reliable.

In VPPA keyhole welding, the welding parameters (standoff distance, voltages or currents, speed of the torch along the weld, and times at the two polarities) are set at values that cause the weld to penetrate the workpiece and the molten metal to flow around the opening in a pattern reminiscent of a keyhole. The conventional method for starting such a weld was to drill a pilot hole to serve as the initial keyhole, carefully align the welding torch over the pilot hole, adjust the standoff distance, and then turn on the torch at full power. The success of this method depended on the operator's ability to perform this alignment and adjustment precisely.

The new starting technique does not depend on precise manual alignment. The welding torch is positioned with no more than the usual care. As the torch begins to move along the weld, the welding current is gradually increased toward the full operating level, causing the depth of the weld to increase gradually until the keyhole is formed (see figure). The standoff is controlled by the automatic-voltage-control portion of the welding equipment. At the end of a circumferential weld, the torch can continue a short distance past the starting point to overlap and thereby complete the weld in the starting transition region.

This work was done by W. F. McGee of Martin Marietta Corp. for **Marshall Space Flight Center**. *No further documentation is available.*



The **Welding Current Is Increased Gradually** over a short distance until the full operating current is reached, and welding proceeds in the "keyhole" mode.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center
Refer to MFS-28268/TN

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Materials

0215 New Permanent Press Cotton Fabric Treatment (Licensing Opportunity)

0216 New Polymers Meet Navy Needs

0217 Self-Priming Topcoat Produced

0218 New Diagram for Predicting Weld Phases

0219 Artificial Voids in Ceramic Materials—Small holes are made deliberately to help quantify techniques of nondestructive evaluation.

0220 Dry PMR-15 Resin Powders—Shelf lives of PMR-15 polyimides are lengthened.

0221 Effects of Radiation on Elastomers—Graphs and tables are presented for synthetic materials.

0222 Powder-Metallurgy Process and Product—Rapid-solidification processing yields alloys with improved properties. (Licensing Opportunity)

0223 Organoborosilane Polymers and Ceramic Products—Ceramics exhibit high thermo-oxidative stability. (Licensing Opportunity)

0224 Sizing Increases Fiber/Matrix Adhesion—Graphic fibers are precoated in a dilute solution of the matrix.

0225 Stabilizing PFAE Against Oxidation—Stabilized, noncorroding perfluoroalkylether can be used at 300 °C as a hydraulic fluid or lubricant.

0226 Uniform Etching for Polycrystalline Photoconductor Films—Prewetting the film surface can help overcome nonuniformity.

Other Items of Interest

0182 Specular Steel Surfaces for Solar Mirror Substrates

0183 Windows for the Future

Research Technology
Agricultural Research Service
U.S. Department of Agriculture

New Permanent Press Cotton Fabric Treatment

Cotton fabrics that have the wrinkle resistance of permanent press can be made with new chemical technology developed by the U.S. Department of Agriculture.

"We think our process opens up a new field that will allow textile makers to produce all-cotton shirts and other apparel that will have the cool feel of cotton, need little if any ironing and still meet industry strength standards," says Clark M. Welch, a chemist with the Agricultural Research Service. "The process works best with textiles containing 50 to 100 percent cotton."

Welch and chemist Bethlehem K. Andrews, based at ARS' Southern Regional Research Center in New Orleans, Louisiana, filed for a patent June 16 on a group of chemicals that produce permanent press—100 percent cotton fabrics that dry smooth without wrinkles even after 65 washings.

Welch says the fabrics are about 20 percent stronger than permanent press fabrics on today's market.

"Polyester or other fabrics are usually blended with cotton to add strength," Welch says. "But polyester doesn't absorb perspiration the way cotton does, so blended shirts don't keep you as cool."

The new fabric treatment has another advantage for consumers: They can take out or put in creases by ironing the fabric. This is difficult to do with permanent press material now on the market.

It will be at least several years, however, before consumers will find these items on clothing store racks. "That's because the chemicals needed to make them won't be available in large quantities at affordable prices for at least 2 years," says Frank X. Werber, ARS' textile expert based at Beltsville, Maryland. "The chemicals are only available for research tests now.

Several textile mills have made and evaluated the new fabrics and "have confirmed our laboratory findings," Welch says. Also, Cotton Incorporated, a trade association sponsored by cotton growers, has tested the fabric treatment and says it has potential.

The new fabric treatment has another important advantage for the textile industry: formaldehyde isn't used. Federal regulatory agencies are pressuring the industry to minimize or remove formaldehyde from current permanent press fabrics because it can irritate the skin and eyes and has caused cancer in laboratory animals. The new process uses chemicals called polycarboxylic acids, which are nontoxic in laboratory studies.

The patent is on four groups of catalysts, or curing agents, that are used to quickly bind the polycarboxylic acids to fibers. The curing agents are similar to chemicals used in baking to control bread rising and in water treatment plants to prevent calcium, magnesium, and other chemicals from building up in pipes and boilers.

In the new process, fabrics soaked in the polycarboxylic acids and the catalysts are heated for about 15 to 90 seconds at temperatures ranging from about 300°F to 500°F. At those high temperatures, the acids unite with the fibers, forming cross-links between the cellulose molecules of cotton fibers and giving wrinkle resistance to the fabric, Welch says.

"The catalysts are the key to our patent," he explains. "Polycarboxylic acids have been known for about 20 years but couldn't be used with previous catalysts. The new ones we're patenting

speed up the reaction of the polycarboxylic acids with the fibers. Without them, the process could take an hour. At such high temperatures, the fabric would burn up."

Welch also says that in lab studies the new process gives off no vapors or odors and does not cause yellowing of the fabric. Previous attempts to use polycarboxylic acids caused off-colors and other problems.

Also, the new fabrics could save the industry money because they can be colored by certain kinds of dyes after being permanent-press treated. Welch says this is important because manufacturers can make clothing out of permanent press fabrics and dye the garments after they find out which colors are most popular with consumers. Textile makers must now dye first and then put in permanent-press treatment, which means they sometimes have large stocks of certain colors that won't sell.

For technical information, contact Clark M. Welch, USDA-ARS Southern Regional Research Center, P.O. Box 19687, New Orleans, LA 70179 (504) 286-4272. Patent application serial number not yet assigned.—**By Sean Adams,** ARS.·

For Additional Information:

Inquiries concerning rights for commercial use of this invention should be addressed to

Office of Federal Patent Licensing
Center for the Utilization of Federal Technology
Room 304, NTIS
Springfield, VA 22161
(703) 487-4738

New Polymers Meet Navy Needs

A team of Naval Research Laboratory (NRL), Washington, D.C., scientists has developed fluorinated polymers with unique and advantageous properties that are fulfilling many Navy requirements both on land and at sea.

Chemists at NRL are applying coatings based on these fluorinated polymers to storage tanks, underwater hulls of surface craft, radomes on submarines and, more recently, as protective linings for aircraft bulk fuel storage tanks.

Three types of fluorinated polymeric materials have resulted from the team's research efforts--epoxies, urethanes, and acrylates. Each material is especially useful for specific applications. The epoxy is ideal as an adhesive or a composite matrix resin; the urethanes provide coatings that resist sunlight, abrasion, and corrosive substances; and, the acrylates are excellent coatings for fiber optics.

In midsummer 1987, aircraft-ready fuel storage tanks at the Corpus Christi Naval Air Station, Texas, were lined with an NRL-developed coating system containing a fluoro-urethane topcoat. This lining system resists attack by fuel and water, which condenses and collects at the bottom of fuel storage tanks. The excellent barrier properties of the fluorourethane topcoat prevent water, oxygen, and other corroding species from reaching the steel, while the nonstick nature of the topcoat extends the time between tank cleaning, and makes cleaning operations faster and easier. Accordingly, the Naval Facilities Engineering Command has specified the NRL fluorourethane lining system for the relining of several large (200,000-barrel capacity) fuel storage tanks in Japan managed by U.S. Naval Fleet Activities, Yokosuka, Japan.

The fluorinated resins patented by NRL are now manufactured and sold commercially.

The NRL coating also provides a fast-draining surface that hastens the runoff of water. Because a film of water on submarine antennas can interfere with the strength and stability of communications, the fast draining of water reduces the time needed to achieve a stable signal. The NRL coating was tested successfully on three Los Angeles-class fast attack submarines before being adopted as the standard coating for antennas on Los Angeles- and Ohio-class submarines.

The chemists report that the excellent anticorrosive properties and easy cleanability of the NRL fluorourethanes have been demonstrated in bilges and tanks onboard ships. They have also been used in experiments on underwater hulls because hard and soft marine organisms initially bond to them only weakly. This coating, together with a regular program of underwater hull maintenance, could possibly serve as an

effective non-toxic substitute to coatings presently in use. The coating has been demonstrated in experimental applications to the underwater hulls of two surface craft and a tug boat.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 130903/TN

NAVY
Domestic Technology Transfer Fact Sheet

Self-Priming Topcoat Produced

The F-14 *Tomcat* was selected to field-test the Navy's new self-priming topcoat. During the fighter's regular fleet duty, the topcoat will be evaluated for 6 to 9 months. At the same time, additional testing will be conducted using H-3 Navy helicopters.

Scientists at the Naval Air Development Center, Warminster, Pennsylvania, have produced a self-priming topcoat. The new product is undergoing tests using the F-14 *Tomcat* fighter aircraft and Navy H-3 helicopters. The specially formulated corrosion-preventive organic coating provides the same or better protection with a single coat as the present two coats, and annual cost savings to the Navy have been estimated at nearly $1.3 million.

The new self-priming topcoat meets or exceeds all the critical performance requirements of Navy's current aircraft paint system, which is a two-coat method -- an epoxy primer and a polyurethane topcoat. In addition to the obvious savings in manpower, material, and painting time, the single coating contains no chromates or leads (toxic substances) and has reduced volatile organic compounds (solvents) released into the atmosphere.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
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Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 130901/TN

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards (NBS)
U.S. Department of Commerce
Gaithersburg, MD 20899

New Diagram for Predicting Weld Phases

NIST researchers have produced a new, more accurate diagram for predicting the ferrite content of stainless steel welds. Knowledge of the ferrite content is important because, when held to within a certain small range, it helps to control the properties of the weld. Too low a ferrite content can cause cracking and too high a content can increase the rate of corrosion. The new diagram, developed in cooperation with the Colorado School of Mines and the Welding Research Council, was produced from a database containing more than 950 alloy composites from worldwide sources. It is more accurate than the two most commonly used diagrams, termed DeLong and Schaeffer.

FOR ADDITIONAL INFORMATION: contact Thomas A. Siewart, Fracture and Deformation Division, NIST, Boulder, CO 80303.

NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Artificial Voids in Ceramic Materials

Small holes are made deliberately to help quantify techniques of nondestructive evaluation.

Silicon carbide and silicon nitride are high-temperature structural ceramic materials that are being considered for application in advanced gas-turbine engines. Pores, small cracks, inclusions, and variations in microstructure are strength-limiting defects commonly observed in these sintered silicon-base ceramics. The ability to detect and characterize voids (by sizes, shapes, and locations) in structural ceramics is vital for increasing the strengths and reliabilities of these materials. Ceramic samples containing seeded voids that have known dimensions and locations are essential for determining the quantitative capabilities of nondestructive evaluation techniques applied to structural ceramics.

A method for creating voids in ceramic specimens has been developed. In an example of the method, plastic microspheres of various sizes were pressed into the surfaces of silicon carbide and silicon nitride "green" bars placed in a die. Additional ceramic powder was added to cover the spheres, and the bars were compacted in such a way that the spheres were buried beneath the surfaces of the bars. The bars were heated to vaporize the spheres, thereby producing internal voids. The bars were then sintered to complete the processing cycle. Several hundred voids ranging in diameter from 25 to 500 μm were thus seeded in SiC and Si_3N_4 specimens.

These voids were fully characterized metallographically and the specimens examined by use of both conventional and projection x-radiography and scanning laser acoustic microscopy. Standard specimens produced and characterized in this way would be of interest to manufacturers of structural ceramic materials and to researchers and developers of nondestructive flaw detection equipment.

This work was done by Don J. Roth, Edward R. Generazio, and George Y. Baaklini of **Lewis Research Center**. *Further information may be found in NASA TM-88797 [N86-31913/NSP] [A02], "Quantitative Void Characterization in Structural Ceramics Using Scanning Laser Acoustic Microscopy."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-14586/TN

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NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Dry PMR-15 Resin Powders

Shelf lives of PMR-15 polyimides are lengthened.

PMR-15 polyimides were developed at the NASA Lewis Research Center in response to the need for processable, high-temperature-resistant matrix resins for fiber-reinforced advanced composites. PMR-15 resins are commercially available from a number of suppliers and are currently being used in a variety of aerospace, aeronautical, and commercial applications.

During the manufacture of a PMR-15 resin, a resin solution is prepared by dissolving monomer reactant in an alcoholic solvent of low boiling temperature. The monomer solution is applied to a reinforcement and the bulk of the solvent removed to form prepreg material, which is then cured at high temperature and pressure to form a composite part.

Before curing, the composition of the resin is continually changing because of monomer reactions that occur during storage. The degree and type of these reactions depend on the storage conditions and the solvent content of the resin. Compositional changes in a resin include the formation of soluble higher esters, which severely affect the processability and properties of the composite, and insoluble imides, which precipitate from solution.

Prepreg materials containing low solvent levels (3 to 5 weight percent) can be stored at temperatures from 0 to 40 °F (−18 to +4 °C) for intervals of 6 months or longer before compositional changes in the resins markedly affect the processing and/or quality of the composites. The storage, before prepregging, of resin solutions that have solvent levels of 30 to 50 weight percent of solvent, is limited to a maximum time of 4 months at reduced temperatures before changes in the resins severely affect the processing and quality of composites. The shelf life of solutions stored at room temperature [75 °F (24 °C)] is limited to 20 days before the reacted materials precipitate.

In a recent study conducted at NASA Lewis Research Center, a simple procedure for significantly extending the room-temperature shelf life of PMR-15 polyimide resin material was developed. The procedure involves the quenching of monomer reactions by the vacuum drying of PMR-15 resin solutions at 70 to 90 °F (21 to 32 °C) immediately after preparation of the solutions. The absence of solvent eliminates the formation of higher esters and reduces the formation of imides to a negligible level. This procedure provides a fully-formulated dry PMR-15 resin powder that can be readily dissolved in the solvent at room temperature immediately before use. Graphite-reinforced composites prepared from dried resin reactant compositions that had been stored at room temperature for 4 months and 11 months provided PMR-15 composites with processing and mechanical properties identical to those of composites prepared from fresh PMR-15 solutions.

This work was done by Raymond D. Vannucci and Gary D. Roberts of **Lewis Research Center**. *No further documentation is available.*
LEW-14573/TN

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NASA Tech Brief
National Aeronautics and Space Administration

Effects of Radiation on Elastomers

Graphs and tables are presented for synthetic materials.

A report provides data on the effects of radiation on elastomers. It quantifies the effects by giving the minimum radiation levels to induce changes of 1 percent and 25 percent in given properties. Electrical, mechanical, and chemical properties are included in the data. The combined effects of heat and radiation are briefly considered. The data are summarized in a graphic form useful to designers.

Synthetic elastomers are especially prone to radiation damage but are essential for such parts as gaskets, seals, insulation, hoses, diaphragms, and o-rings. Radiation tends to change an elastomer from a rubbery material to a brittle one that no longer fulfills its functions.

Graphs show the tensile-strength and elongation data for various materials, including fluorocarbons, silicones, and polybutadienes. Curves for the variation in electrical resistivities with radiation doses are also presented for selected elastomers.

Radiation-caused chemical changes are important because optical and thermal systems can become coated and because humans can be poisoned by gases given off by elastomers. The report tabulates outgassing by several elastomers and notes that polychloroprene and styrene/butadiene rubber evolve gases at particularly low rates.

The report calls for more work to define completely the responses of elastomers to nuclear radiation. The effects of radiation dose rates and the synergistic effects of temperature, radiation, and atmospheric constituents should be explored.

This work was done by Frank L. Bouquet of Caltech for **NASA's Jet Propulsion Laboratory**. *"Radiation Data on Elastomers for Designers of Spacecraft and Nuclear Power Plants,"*
NPO-16747/TN

Choosing an Alloy for Automotive Stirling Engines

Twenty alloys are evaluated for resistance to corrosion, permeation by hydrogen, and high temperature.

A report describes a study of the chemical compositions and microstructures of alloys for automotive Stirling engines. Stirling engines offer the advantages of high efficiency, low pollution, low noise, and the ability to use a variety of fuels.

In an automotive Stirling engine, tubes containing hydrogen, the working fluid, are heated by flames from the burning fuel. For an adequate rate of transfer of heat to the hydrogen, the walls of the tubes must be no thicker than about 0.75 mm. The tube material must be strong enough to contain the hot, high-pressure hydrogen.

Automotive designs call for a peak hydrogen pressure of 21 MPa. The temperature on the flame side will be about 870 °C. Moreover, the tubes must last for at least 3,500 h under such conditions, corresponding to an engine driving life of 100,000 mi (160,000 km).

In the study, 20 alloys — 14 iron-based, 5 nickel-based, and 1 cobalt-based — were evaluated for resistance to oxidation and corrosion, permeability by hydrogen, and endurance. The iron-based alloys were considered the primary candidates because of their low cost. The nickel-based alloys were regarded as a second choice in case a suitable iron-based alloy could not be found. The cobalt-based alloy was included for comparison but was not a candidate, because cobalt is an expensive strategic material.

An iron-based alloy, CG-27, was selected as the material for Stirling-engine heater tubes. It was the only material that did not fail by creep rupture in engine tests. Moreover, it resisted oxidation and corrosion and formed thin, tenacious oxide layers on its surfaces that act as barriers to permeation by oxygen from outside and by hydrogen from inside the tube.

This work was done by Joseph R. Stephens of **Lewis Research Center**. *Further information may be found in NASA TM-87250 [N86-20541/NSP], "Alloy Chemistry and Microstructural Control to Meet the Demands of the Automotive Stirling Engine." [A03]*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-14609/TN

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Powder-Metallurgy Process and Product

Rapid-solidification processing yields alloys with improved properties.

Ingot-metallurgy (I/M) 2XXX-series aluminum alloys based on Al/Cu and Al/Cu/Mg are widely used in aircraft structures where fatigue and fracture resistance and elevated-temperature strength are important design considerations. A systematic study was undertaken to extend the favorable property combinations of I/M 2XXX alloys through the recently developed technique of rapid-solidification processing using powder metallurgy (P/M). The benefits of rapid-solidification processing of P/M 2XXX aluminum alloy compositions over I/M processing were evaluated by comparison with an I/M control alloy.

Rapid-solidification processing, a technology that has greatly expanded the range of compositions and microstructures attainable in metallic materials, typically involves the impingement of a molten metal stream onto a rapidly-spinning chill block or through a gas medium using a gas atomization technique. The Al/Cu/Mg alloys used in this study, which contained various amounts of zirconium, were produced by air atomization of fine powders. The average powder size was maintained between 12 and 15 μm. After atomization, the powders were consolidated into billets and the billets extruded into bars. Standard metallographic procedures were used to examine the microstructures, and mechanical testing was performed with specimen configurations and procedures according to American Society for Testing and Materials standards. Standard tensile, Charpy V-notch, and fracture-toughness tests were performed on the extruded bar in naturally aged and artificially aged conditions.

By and large, the rapid-solidification-processed P/M alloys exhibited strength and toughness properties substantially improved over those of the I/M-produced alloys. Zirconium additions of as high as 0.6 weight percent were used successfully to enhance the alloy properties, while the practical limit of zirconium addition in I/M alloys is about 0.10 to 0.15 weight percent. One promising Al/Cu/Mg/Zr alloy composition was also evaluated in the product forms of plate and sheet. These product forms had a marked advantage in tensile properties and toughness due to the ability of the P/M microstructure to control better the recrystallization and the grain-growth processes. The results of this study indicate that rapid-solidification processing of P/M alloys has the potential of producing 2XXX-series aluminum alloys with strength and toughness properties superior to those of I/M-produced alloys.

This work was done by Henry G. Paris of Aluminum Co. of America for **Langley Research Center.** *Further information may be found in NASA CR-172521 [N87-20406/NSP][A05], "Development of Powder Metallurgy 2XXX Series Al Alloy Plate and Sheet Materials for High Temperature Aircraft Structural Applications."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457(f)], to the Aluminum Company of America. Inquiries concerning licenses for its commercial development should be addressed to

Manager, Technology Marketing Dept.
Aluminum Company of America
1501 Alcoa Building
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NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

Ames Research Center, Moffett Field, California

Organoborosilane Polymers and Ceramic Products

Ceramics exhibit high thermo-oxidative stability.

Processes have been developed to make polyorganoborosilane polymers. These polymers are useful principally as precursors to ceramics that withstand high temperatures. In a representative application, the polymer might be drawn into fibers, and then pyrolyzed to produce a ceramic cloth.

In the laboratory, polymers are prepared by coupling reactions of boron halides or organoboron halides with organic halosilanes in an aprotic solvent that has been dried and degassed to remove water and oxygen to the extent possible. In a typical reaction (see Figure 1), 4 to 6 equivalents of an alkali metal are freshly cut and added to the solvent at ambient temperature. The reactants are combined in equimolar amounts and slowly added dropwise to the solvent.

The reaction mixture of solvent plus reactants is refluxed at 120 to 160 °C for 16 to 24 hours. Then an alkyl iodide is added and the reflux continued for an additional time up to 4 hours to consume the excess alkali metal and thereby quench the reaction. The reaction products include the polymers and a precipitate consisting of the alkali halide.

After cooling, the reaction products minus the precipitate are filtered. The filtrate is washed with additional aprotic solvent, then dried in a partial vacuum to obtain the polymers, which usually have molecular weights of 800 to 1,300 daltons. The polymers are generally soluble in organic solvents and melt at temperatures below 150 °C.

To produce ceramic material, a polymer or mixture of polymers is pyrolized in nitrogen at temperatures from 600 to 1,100 °C. The resulting ceramic has high thermo-oxidative stability (see Figure 2): it resists both oxidation and weight loss when exposed in air to temperatures up to 1,100 °C.

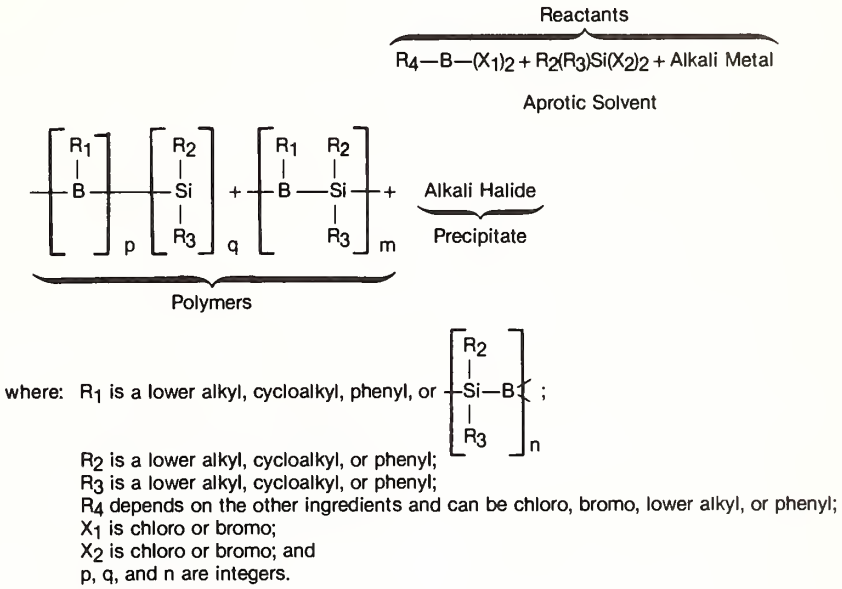
Reactants
$R_4—B—(X_1)_2 + R_2(R_3)Si(X_2)_2$ + Alkali Metal
Aprotic Solvent
Alkali Halide
Precipitate
Polymers
where: R_1 is a lower alkyl, cycloalkyl, phenyl, or
R_2 is a lower alkyl, cycloalkyl, or phenyl;
R_3 is a lower alkyl, cycloalkyl, or phenyl;
R_4 depends on the other ingredients and can be chloro, bromo, lower alkyl, or phenyl;
X_1 is chloro or bromo;
X_2 is chloro or bromo; and
p, q, and n are integers.

Figure 1. The **Precursor Polymers** are prepared by using an alkali metal to couple a boron halide with an organohalosilane.

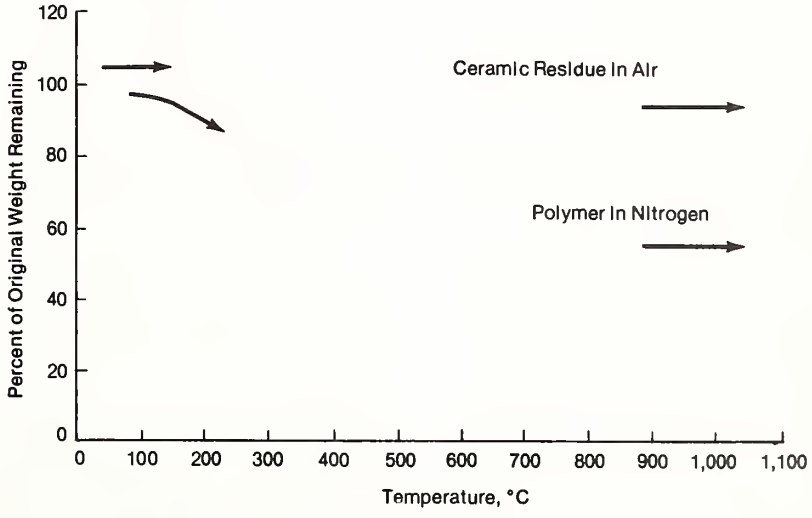

Figure 2. **Thermogravimetric Analysis** of a polymer prepared from dimethyldichlorosilane and methylboronidibromide shows the loss of weight as the polymer is heated in nitrogen. The resulting ceramic residue shows no weight loss or gain when subsequently heated in air.

This work was done by Salvatore R. Riccitiello of **Ames Research Center** *and Ming-ta Hsu and Timothy S. Chen of H. C. Chem Research and Service Corp. For further information, circle the number listed at the end of this article.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center. Refer to ARC-11649/TN

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Sizing Increases Fiber/Matrix Adhesion

Graphite fibers are precoated in a dilute solution of the matrix.

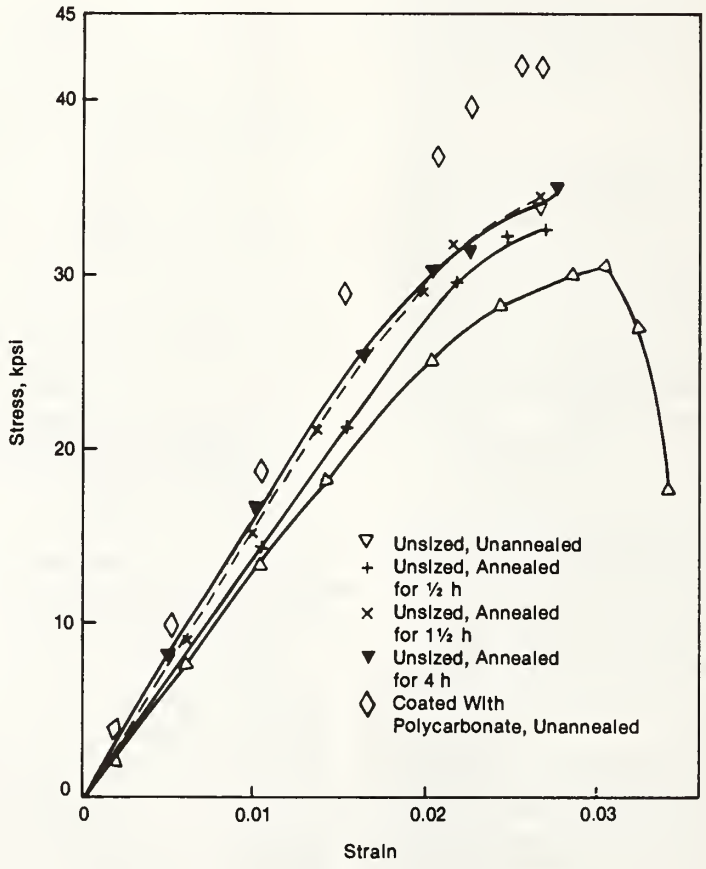
Experiments have shown that the strengths of graphite fiber/polycarbonate matrix composites are increased by precoating ("sizing") the fibers with a thin layer of polycarbonate. It is widely recognized in the industry that sizing can promote the wetting of fibers by matrix polymers, thereby enhancing fiber/matrix adhesion; however, until now the proprietary nature of commercially sized fibers has made it difficult to investigate the factors that determine the effectiveness of sizing.

The graphite fibers to be sized were immersed in a solution of 0.1 weight percent of polycarbonate in methylene chloride for ½ h, then drained and dried at 65 °C in an air-circulating oven for about 1 h. From the length [0.25 in. (6.35 mm)], diameter (8 μm), and weight gain of the fibers (0.65 percent), the thickness of the polycarbonate coating on the fibers was estimated to be 125 Å.

Composite mats were formed by pressing mixtures of sized or unsized graphite fibers and polycarbonate flakes at a temperature of 275 °C and a pressure of 5,000 psi (34 MPa) for 15 min, then allowed to cool slowly to room temperature while remaining under pressure. Some of the samples were annealed in the press by maintaining them at 245 °C for various intervals from ½ to 4 h before allowing them to cool to room temperature.

Specimens were cut from the composite mats and subjected to three-point bending tests to fracture, to determine their flexural strengths and moduli. As shown in the figure, the flexural strength of the specimens made from unsized fibers was increased by annealing. However, the unannealed specimens made from sized fibers showed the greatest strength of all.

The question of the molecular structure of the fiber/matrix interface in the sized specimens has not yet been addressed. However, x-ray diffraction analysis of the unsized specimens showed that annealing causes the matrix polymer to crystallize partially on and around the graphite fibers.



The Flexural Strengths of composite samples were measured to determine the effects of different fabrication conditions.

Such crystallinity was previously known to be caused by exposure to solvents or by annealing above the glass-transition temperature and may be responsible for the enhancement of the fiber/matrix bonding.

This work was done by Muzaffer Cizmecioglu of Caltech for **NASA's Jet Propulsion Laboratory**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Stabilizing PFAE Against Oxidation

Stabilized, noncorroding perfluoroalkylether can be used at 300 °C as a hydraulic fluid or lubricant.

A new process makes commercial perfluoroalkylether (PFAE) hydraulic fluid more stable in the presence of metals in hot oxidizing atmospheres. The viscosity and molecular weight of the treated fluid are almost identical with those of the untreated fluid.

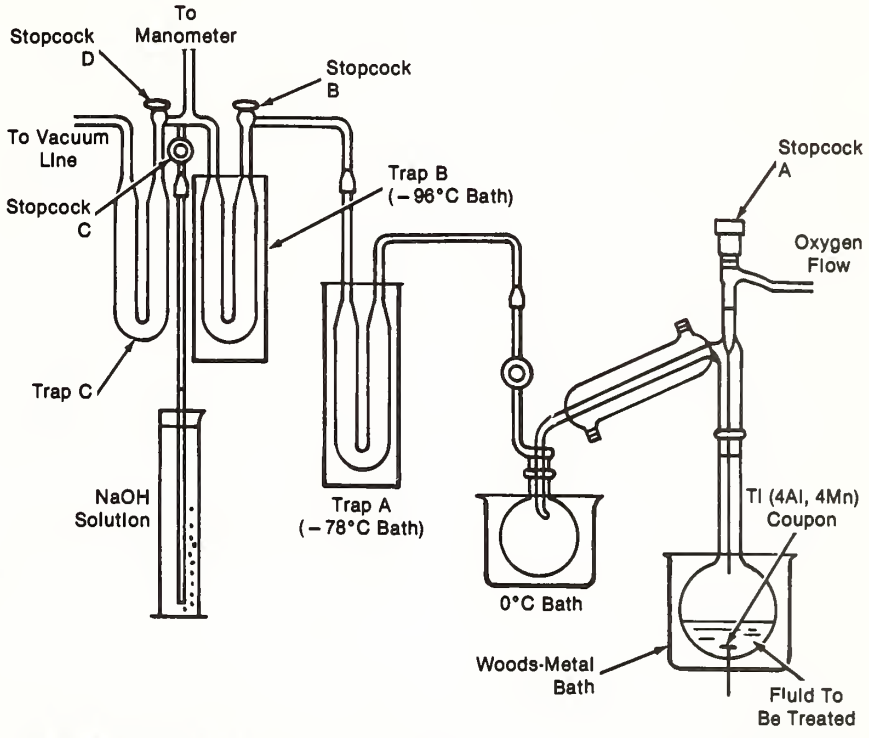
The process consists of thermal oxidation in the presence of a catalyst (see figure) to remove weak links, followed by transformation of the newly-created functional groups into phospha-s-triazine linkages, which impart antioxidation and anticorrosion properties. A 66-percent yield of stable PFAE is obtained.

The thermal-oxidative stability of the treated fluid is better than that of the starting material by a factor of 2.6×10^3, on the basis of the amounts of volatile materials evolved during exposure for 8 hours to an oxidizing atmosphere in the presence of Ti(4Al, 4Mn) alloy. Furthermore, no corrosion occurred in the titanium alloy samples in these tests.

The fluid can be used as a lubricant, grease, or hydraulic fluid at temperatures from −55 to +300 °C in the presence of metals in an oxidizing atmosphere. No other lubricant now available offers this combination of properties.

This work was done by W. R. Jones, Jr., of **Lewis Research Center** *and K. Paciorek and R. Kratzer of Ultrasystems. Further information may be found in NASA TM-87276 [N86-25474/NSP][A02],* *"Improved Perfluoroalkylether Fluid Development."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-14612/TN



This **Laboratory Apparatus** is used in the first step of the production of stabilized PFAE. The traps are used to collect volatile fractions for analysis. The involatile residue is treated further to transform it into stabilized PFAE.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Goddard Space Flight Center, Greenbelt, Maryland

Uniform Etching for Polycrystalline Photoconductor Films

Prewetting the film surface can help overcome nonuniformity.

Prewetting the surface can overcome the problem of the nonuniformity of etching that often occurs in such polycrystalline films as PbS and PbSe. These films exhibit variations in the size and packing of crystallites. Prior to the prewetting method, severe undercutting of detector material occurred when single-element photodetectors and arrays were etched on preprocessed silicon wafers.

For example, in attempts to delineate 128-element arrays of PbS with a 30-μm pitch (22 μm wide with 8-μm separations) on preprocessed silicon wafers (92 chips per wafer), undercutting was so severe that many elements were washed away. If etching were stopped just short of the undercutting, some areas would remain coated with the unwanted PbS.

When the prewetting method is applied to these arrays, the substrates are soaked for one minute in a suitable wetting agent; for example, Kodak Photo-Flo (or equivalent) mixed in the ratio of one part agent to 200 parts of water. Then the substrates are immersed in etching solution. The unwanted PbS, which, in this case, covers 99.9 percent of the substrate, is removed entirely, with only a few micrometers of undercutting.

It is believed that prewetting causes the etchant to attack the film uniformly. Because this process involves wet chemistry, it is both inexpensive and easy to use.

The prewetting method has also been used successfully on PbSe films. The Photo-Flo (or equivalent) wetting agent used in the tests is compatible with the AZ1450J (or equivalent) photoresist that is used for delineating photoconductor patterns.

This work was done by John Barrett of Itek Corp. for **Goddard Space Flight Center**. *For further information*
GSC-12969/TN

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Medicine & Biology

0227 Computer-Assisted Dental Emergency Diagnosis System Being Developed

0228 New Developments Available to Test Marine Plankton Light Emissions

0229 Experimenting with Baroreceptor Reflexes—The carotid arteries are stimulated by pressure or suction on the neck. (Licensing Opportunity)

0230 Measuring Time-Averaged Blood Pressure—An instrument removes the dynamic component so that only the average component remains.

Other Items of Interest

0157 Gene Transport Vehicles Found in Yeasts

NAVY
Domestic Technology Transfer Fact Sheet

Computer-Assisted Dental Emergency Diagnosis System Being Developed

Scientists at the Naval Dental Research Institute, Great Lakes, Illinois, are developing a computer system capable of assisting an independent duty hospital corpsman in the diagnosis and initial treatment of dental emergencies. The system generates definitive diagnoses based on the patient-user-system interaction and a specific treatment plan is provided for each of these diagnoses. The system can also provide a differential diagnosis of soft tissue lesions, permit the review of definitions, or generate treatment plans directly without utilizing a diagnostic sequence. Preliminary validation results are favorable.

The system was tested in a large Navy dental clinic with actual emergency patients. Participating dental technicians have a working knowledge of basic medical care, infections, inflammation, normal tissue parameters, medical terminology, and a cursory knowledge of oral and facial structures. Following training on the system, a dental technician performed a brief examination on each of 80 symptomatic patients, entering responses to computer-displayed questions. Resulting computer-generated diagnoses were recorded. The entire process in each case required approximately 5 to 7 minutes per patient. After preliminary diagnosis, the patients were referred to one of several dentists for independent evaluation. In order to standardize terminology, the dentists were given a list of the 35 diagnoses included in the program and told to select, if possible, their diagnoses from the list. They were also asked to categorize their diagnoses as either "probable" or "possible" self-evident situations. The system could be used to provide supplementary diagnostic information for health care providers and to perform prediagnoses of patients in dental clinics.

The system can organize or clarify important parameters that can dictate treatment such as the condition of the tooth before trauma, size of a pulp exposure, and location of a fracture. Consequently, several of the trauma-related diagnoses are based on different treatments for the same diagnosis. In this sense, the computer system can greatly assist these seemingly self-evident situations. The system could be used to provide supplementary diagnostic information for health care providers and to perform prediagnoses of patients in dental clinics.

Some of the questions and logic will require further testing and restructuring.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 130702/TN

New Developments Available to Test Marine Plankton Light Emissions

Scientists at Naval Ocean Systems Center, San Diego, California, have developed a test chamber for determining the light emissions of planktonic organisms. The basic instrument has been used extensively since 1981. However, a new instrument can now be used that employs the same basic technique but uses an integrating sphere for light collection.

A light tight chamber is used that has at least one light port (preferably two) where photomultiplier tubes are connected to the test chamber for detecting and measuring the flash kinetics of marine organisms. A door is pivotally mounted on the chamber so an organism sample holder can be inserted and removed. Then, a vacuum line is connected to the test chamber and to the sample holder through a passageway so that the organism can be excited by drawing off the fluid containing the organism. The light emissions of the sample can be detected and measured by photomultiplier tubes.

Ideally, a third port is added to which another multiplier tube is connected providing a different orientation to the organism in the sample holder. Alternate experiments can be conducted on the organism through the third port. The collected data can help identify which organisms are responsible for the light emissions in the surface waters of the world's oceans.

For Additional Information:

Backup material on this effort is available from:

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Naval Surface Weapons Center
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Refer to 130805/TN

NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Licensing Opportunity

Experimenting With Baroreceptor Reflexes

The carotid arteries are stimulated by pressure or suction on the neck.

A chamber strapped to the neck of a human subject applies pressure or suction of controlled magnitude and duration to the carotid arteries. The chamber, called a Baro-Cuff, was developed to study the blood-pressure-reflex responses of astronauts in outer space. It may also be useful for terrestrial studies of patients with congestive heart failure, chronic diabetes mellitus, and other conditions in which the blood-pressure-reflex controls behave abnormally.

The chamber stimulates baroreceptors — the body's blood-pressure sensors — in the carotid arteries. Meanwhile, instruments measure and display the pressure in the chamber and the subject's electrocardiogram and respiration. Researchers can thus observe responses to a variety of stimulus patterns.

The Baro-Cuff is molded uniquely to fit the front of the subject's neck so that it provides a seal for both positive and negative pressures. The seal leaks so little that a bellows can be used instead of a pump to change the pressure in the chamber (see figure). The bellows, driven by a stepping motor, is smaller and quieter than a pump and uses less power. The bellows sets the pressure in the range from −65 to +40 mm of mercury (−8.7 to +5.3 kPa) — within the limits of comfort of most human subjects.

A microprocessor chip controls the stepping motor and collects the data. Erasable, programmable, read-only memory chips store custom software for the microprocessor. The software can be modified as necessary to change the timing, amplitude, polarity, rate of change, intensity, and duration of pressure. The system can change pressure at a rate fast enough to stimulate rate-sensitive receptors — that is, above about 300 mm of mercury (40 kPa) per second.

In the outer-space application, the subject conducts the experiments. The subject sets thresholds with the aid of cursors on an electrocardiogram and respiration signals displayed on an oscilloscope. After establishing a normal respiratory cadence, the subject presses a button on a keypad to start an experiment. The subject then breathes two more times and holds his or her breath for 4 s.

At this point, the pressure in the chamber is increased. The microprocessor adjusts the bellows during the next four heartbeats to keep the pressure in the chamber close to 40 mm of mercury (5.3 kPa). After this interval, successive *R* waves of the electrocardiogram trigger reductions in pressure to 25, 10, −5, −20, −35, −50, and −65 mm of mercury (3.3, 1.3, −0.1, −2.7, −4.7, −6.7, and −8.7 kPa, respectively). After the last decrement, the system returns the pressure to the ambient level for two heartbeats, then sounds an alarm to tell the subject to breathe again.

The sequence is repeated seven times to complete a session. The subject measures his or her blood pressure manually before the first sequence and after the third and seventh sequences and keys the values into the microprocessor. At the end of a session, the system displays average *R-R* intervals and chamber pressures for each step.

This work was done by Dwain L. Eckberg of Virginia Commonwealth University and Ross L. Goble of Engineering Development Laboratory for **Johnson Space Center**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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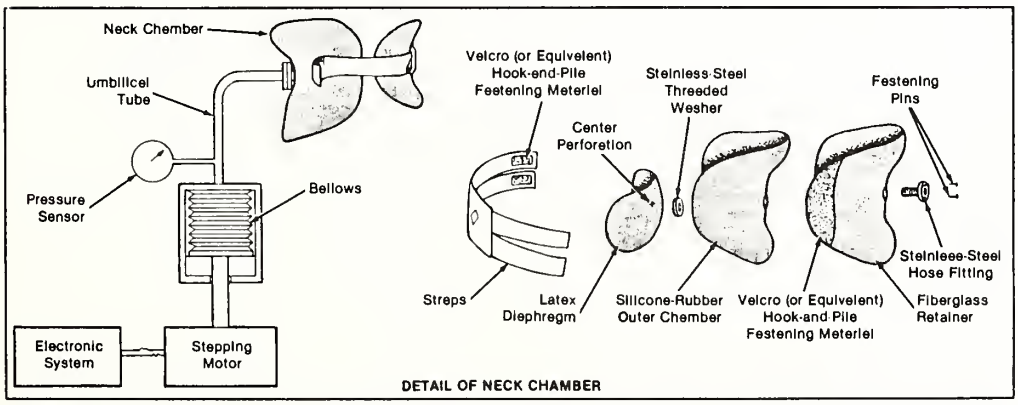

The **Baro-Cuff** is a silicone-rubber chamber that fits on the front of the subject's neck. The electronic system, stepping motor, bellows, and umbilical tube furnish controlled pressure to the chamber. The pressure sensor provides feedback to the microprocessor in the electronic system.

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NASA Tech Brief
National Aeronautics and Space Administration
Goddard Space Flight Center, Greenbelt, Maryland

Measuring Time-Averaged Blood Pressure

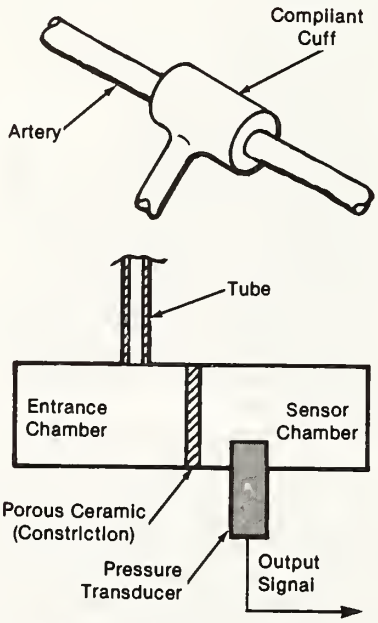
An instrument removes the dynamic component so that only the average component remains.

A device measures the time-averaged (static) component of absolute blood pressure in an artery instead of the usual diastolic and systolic extremes of pressure created by the heart's pumping action. The device includes a compliant cuff around the artery and an external monitoring unit.

The cuff is connected to the monitoring unit through a flexible tube. The cuff, tube, and monitoring unit are filled with an isotonic fluid, which transmits the pressure from the artery to the monitoring unit.

A ceramic constriction divides the monitoring unit into two chambers (see figure). The constriction filters out the dynamic component of pressure in the entry chamber so that only the time-averaged pressure component is present in the sensor chamber. An electrical transducer in the sensor chamber produces a signal indicative of the pressure.

This work was done by Neil S. Rothman of The Johns Hopkins University, Applied Physics Laboratory. No further documentation is available. GSC-13044 /TN



The Ceramic Constriction in the Monitoring Unit suppresses the ebb and flow of pressure-transmitting fluid in the sensor chamber. The transducer thus measures only the static component of the blood pressure.

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Natural Resources Technology & Engineering

Software

0231 VICAR/IBIS Software System—A collection of programs provides extensive capabilities for the manipulation of imagery and geographical data.

VICAR/IBIS Software System

A collection of programs provides extensive capabilities for the manipulation of imagery and geographical data.

The VICAR/IBIS software system is a combination of the JPL VICAR (Video Image Communication and Retrieval System) image-processing system and the JPL IBIS (Image Based Information System) geographic-information-management system. The VICAR/IBIS system provides the user with extensive general-purpose image-processing capabilities, as well as an information-management system for accepting, converting, and operating on vector (graphical) and tabular data. The system can be used to perform various image-processing functions on any sort of digitized image data, including such remotely sensed data as those from the Landsat multispectral scanner.

The available image-processing functions include picture comparison, picture expansion with noise elimination, convolution filtering, geometric transformations, Fourier transformations, and many other manipulation and enhancement capabilities. In addition, the user is provided with an information-management system designed specifically for handling data related to images and the merger of image data with other types of data files. The VICAR/IBIS system offers the user a powerful system for analyzing, manipulating, and managing image data.

The IBIS system offers a computer-based approach to the management of geographical-information systems. By grouping selected functions from the IBIS library, a variety of spatial phenomena can be investigated. Tabular and graphical data can be stored in registration with imagery data in the form of overlaid data planes. Information can be derived from simple associations and comparisons between two or more data files or from more complex procedures including polygon overlay and cross-tabulation.

The VICAR program library is readily used for the generation, input, output, and processing of image data for the IBIS system. The image analyst can use the VICAR/IBIS system with a minimum of programming knowledge, a simple understanding of the operation of the system, and a minimum of input data. The analyst calls for automatic execution of one or more of the system programs, including the requisite image-data-management services, through a set of command instructions.

The programs of the system are written to be flexible in application, with the user supplying only the parameters specific to a particular application. The system provides special-purpose input/output routines designed for the efficient transfer of image data with reduced memory requirements. New applications programs can be easily incorporated into the VICAR/IBIS system as they are developed.

The VICAR/IBIS system is available for a period of 10 years to approved licensees. The licensed program product delivered includes the source code and supporting documentation. Additional documentation may be purchased separately at any time.

The VICAR/IBIS system is a system of programs and control procedures designed for batch execution and is available in two machine implementations. The IBM version is written in FORTRAN IV, Assembler, and OS JCL and has been implemented on an IBM 360-series computer with a minimum central-memory requirement of approximately 140K of 8-bit bytes. The IBM version of the VICAR/IBIS system was released in 1979. The VAX version is written in C and FORTRAN 77 and has been implemented on a DEC VAX-series computer operating under VMS 4.4 with a minimum disk quota of 150,000 blocks. The VAX version was released in 1987.

This program was written by Daniel F. Stanfill IV and Michael A. Girard of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, Circle 10 on the TSP Request Card. NPO-17081/TN*

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Physical Sciences

0232 Automatic Astroposition Determination Apparatus (Licensing Opportunity)

0233 Impersonal Eyepiece for Astronomic Positioning (Licensing Opportunity)

0234 Application of Prony's Method to Data on Viscoelasticity—The Prony coefficients are found by a computer program without trial and error.

0235 Calculating Optical-Transmitter Radiation Patterns—A new formula gives more-accurate gains and pointing losses.

0236 Pulsed Source of Energetic Oxygen Atoms—Oxygen molecules are dissociated by an infrared laser beam. (Licensing Opportunity)

Software

0237 Rational-Spline Subroutines—Smooth curves can be drawn among plotted data more easily.

0238 Tunable Microwave Cavity for Ion Source—Positions of components are adjusted for resonance. (Licensing Opportunity)

0239 Three-Dimensional Complex Variables—Recent theoretical advances are reported.

Testing & Instrumentation

0240 Photometer Tracks the Sun—An instrument is designed for use aboard an aircraft. (Licensing Opportunity)

0241 Detecting Space Dust Particles—The precise times of specific impacts are measured. (Licensing Opportunity)

Other Items of Interest

0178 Isolated Data Acquisition in Hostile Environments

0179 Optical Tool Characterizes Electronic Materials

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Automatic Astroposition Determination Apparatus

Traditionally, the position of the stars and their transits have aided astronomers in the task of determining their positions on earth. A meridian circle or theodolite was the only instrument needed. In using manual instruments such as these, however, the resolution and accuracy of determining a star's transit and tracking the star depend fully on the observer's reaction time. This is too erratic for calculating accurate, precise positions.

As a result, different types of automatic star trackers were proposed. Most of these were based on a system of cross hairs mounted in front of a photodetector. When the cross hairs were rotated, a star's image would pass over them. The star image caused the photodetector to emit a series of pulses that corresponded to the intercepted lines. The pulses were then interpreted to determine the path of the star's image over the cross hairs and the corresponding astroposition of the star being tracked.

Although automatic star trackers were fairly simple to use, they were not suitable for many applications, such as precise star-position measurements needed for accurate and precise astronomic longitude determination. Observers wanted the capability of measuring star transits "as a function of time" (the unique time recorded as a star crosses the observer's meridian), and star trackers did not offer this benefit.

Aware of these circumstances, several individuals set out to research the subject. Their investigations led to several reports which were subsequently published, including the "Center of Mass Measurement Using an Array System" and "Automated Longitude Determination with the Sensing Array."

Using this research as their foundation, William A. Allen and Dr. Pi-Fuay Chen, who both worked on the above-mentioned reports, decided to investigate the evaluation, testing and analysis of sensing arrays as a potential first-order longitude determining system. Allen and Chen established several goals for incorporation in the instrument's design: it could be adapted to determine both longitude and latitude without excessive calculations (latitude determination was deferred), it would provide measurements of star transits as a function of time, and it could be used to implement the Center of Mass Measurement Technique. (This technique is needed to compute the exact center of a star image since the image covers more than a single array element.)

Allen and Chen met these objectives with their invention of the *Automatic Astroposition Determination Apparatus.* Little did astronomers know that they would soon have at their disposal an instrument that would provide precise time and accurate measurements from star transits.

The inventors' road to success began with the modification of the T-4 theodolite. They replaced the instrument's optical micrometer with a square photosensor array. Comprising many precisely positioned, highly miniaturized photosensors, the array is self-scanning. When used with dedicated circuitry, it can measure and track the position of the star image on the array. Since the star's image is focused at a location on the surface of the photosensor array, there is no need for direct human observation.

To determine astronomic longitude with the modified theodolite, the star is observed during meridian transit, and the

array is positioned so that the star image passes perpendicularly across rows of photosensor array elements. The apparatus determines which row of the array the star image covers at a given time. Since the array elements are always scanned from top to bottom and the star image may cover more than one row of array elements, two separate circuits must be available to detect the leading edges of upward and downward star images respectively.

This invention has fulfilled astronomers' needs. The large number of identical and equally spaced array elements, typical to the apparatus, provides a convenient means for obtaining repeated measurements of star transits. This repetition, in turn, allows for improved accuracy over previously used star trackers because an average value may be obtained. Also, the array's square coordinate configuration gives the user an option to employ the Center of Mass Measurement Technique, which results in a high system accuracy.

Applications to government and industry

This invention is targeted primarily toward determining first-order astronomic longitude. Any facility conducting work that requires astronomic longitude information for missile launching can use this technology.

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Fort Belvoir, VA 22060-5546

Impersonal Eyepiece for Astronomic Positioning

The celestial observer has been recognized for some time as one of the major weaknesses in astronomic positioning, a technique for determining orientation on earth.

Edward F. Roof, of USAETL's Topographic Developments Laboratory, trained observers for five years. He found that it was difficult for observers to make consecutive accurate observations. This inspired Roof to explore an electronic star-tracking technique that would eliminate all personal equation errors. He reasoned that such a technique would make star tracking easier on the observer and thereby substantially increase the number of good observers trained.

Roof studied the operation of the Hunter shutter eyepiece, a device which can be attached to a survey instrument to automatically time successive observations of a star's movement. Although the Hunter eyepiece reduces the timing inaccuracies that are characterisitic of human observation, Roof found that it was not practical for all surveying systems. A description of the eyepiece and how it operates will illustrate why.

Automatic timing is accomplished by a movable shutter positioned in front of a glass plate. The shutter is opened for 70 to 100 milliseconds—just long enough to expose the star and enable the observer to study its position relative to the reticle (system of cross hairs in the focus of an optical instrument's eyepiece). The observer then records the time the shutter is opened and the corresponding estimated position of the star. Because the shutter is mechanical, it puts off vibrations that affect the associated surveying instrument. Thus, the eyepiece cannot be used with surveying instruments, like astrolabes, that use mercury pools or pendulum systems.

Roof made several other observations concerning the Hunter eyepiece. Because of its moving parts, it is prone to mechanical failure. Also, the shutter is a drawback to surveying because it masks the star.

Using the principles of the Hunter eyepiece, Roof invented the *Impersonal Eyepiece for Astronomic Positioning.* This eyepiece continuously passes light from a selected star so that the observer can view stars having low-intensity or high-background lighting. In addition, it operates electronically, with no moving parts or disturbing vibrational effects, for increased reliability. A timing device controls the light illumination. Each time the cross hairs are illuminated, the observer calls out a number which represents the star's position against the background of the cross hairs. These numbers are picked up by a voice-activated computer or a tape recorder. The star data are now loaded in the computer and can be accessed by identifying the star number. Following observations, data reduction can be done for determining the observer's position.

Applications to government and industry

This invention can be used for determining deflection values and precise astronomic azimuths. The scientific community can use this technology for observing changes in deflections of the vertical. It can determine the slope of the geoid which is useful information in earthquake-prone areas and in highly active volcanic areas.

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Application of Prony's Method to Data on Viscoelasticity

The Prony coefficients are found by a computer program, without trial and error.

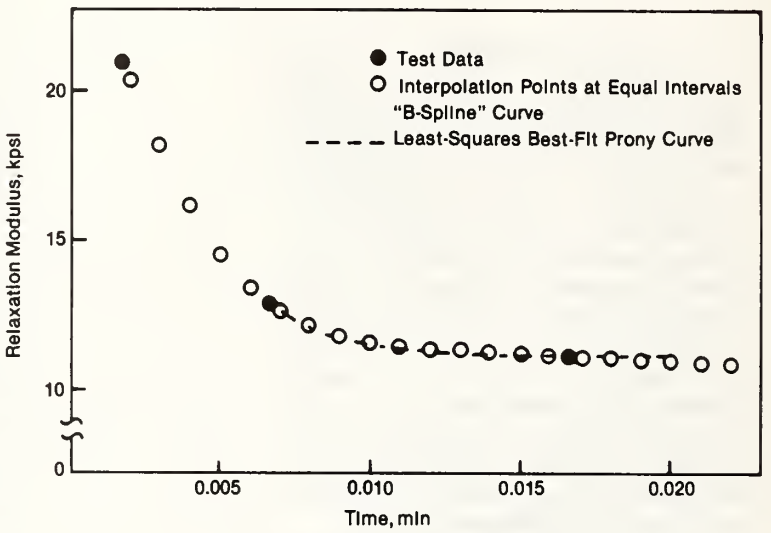
A computational method and computer program have been developed to exploit the full potential of Prony's interpolation method in the analysis of experimental data on the relaxation modulus of a viscoelastic material. Because the relaxation modulus has a component that decays with time, it is well approximated by the first few terms in the Prony series

$$\bar{f}(t) = A + \sum_{i=1}^{m} B_i C^{\gamma_i t}$$

where $\bar{f}(t)$ denotes the approximation to the true value $f(t)$ of the relaxation modulus (or other quantity) that varies with time, A and the B_i and γ_i are the Prony coefficients that are sought, and t = time.

Typically, experimental values of $f(t)$ are available for discrete times t_k at unequal intervals. Heretofore, there have usually been too many unknowns for the number of data points and equations, making it necessary to solve for A and the B_i by trial and error, using assumed values of the γ_i. Moreover, it has not been possible to exploit the full capabilities of Prony's method because the method, in its traditional form, cannot give the best-fit curve through a set of data unless the data are at equal intervals of time.

In the new method, the first step is to fit the experimental data with a curve composed of a succession of third-degree curves. This is done with the help of the "B-spline interpolation" feature that is incorporated into the Intergraph Interactive Graphics Design System computer program. This interpolation is then used to manufacture data at the equal intervals required to obtain the Prony coefficients.



The Prony Interpolation Curve is chosen to give a least-squares best fit to a "B-spline" interpolation of experimental data.

The FORTRAN computer program PRONY calculates the γ_i from the roots of an mth-order equation, the coefficients of which are obtained through a matrix equation in products of differences between equal-interval-interpolated values. Using the calculated values of γ_i, the coefficients A and B_i are then chosen to make the least-squares best fit of the Prony curve to the B-spline curve (see figure).

This work was done by Pedro I. Rodriguez of **Marshall Space Flight Center.** *Further information may be found in NASA TM-86579 [N87-17455/NSP], [A03] the Analytical Determination of Relaxation Modulus of Viscoelastic Materials by Prony's Interpolation Method."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650.

Rush orders may be placed for an extra fee by calling (800) 336-4700. MFS-27179/TN

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Calculating Optical-Transmitter Radiation Patterns

A new formula gives more-accurate gains and pointing losses.

A set of approximate formulas predicts the angular dependence of the far radiation field of a coherent optical transmitter, the telescope of which has a central obscuring disk (for example, a reflecting telescope). The formulas are derived without recourse to the simplifying assumption of uniform plane-wave illumination used to derive the less-accurate traditional formulas.

Assuming illumination by a laser with a Gaussian beam, the telescope gain, g_t, is given by

$$g_t = 2(\pi D/\lambda\alpha)^2[\exp(-\alpha^2) + \exp(-\alpha^2\gamma^2)]^2$$

where D is the telescope aperture diameter, λ is the wavelength, γ is the ratio of the diameter of the obscuring disk to that of the aperture, and α, which is related to the size of the cross section of the Gaussian beam, is given by $1.12 - 1.30\gamma^2 + 2.12\gamma^4$. This formula is not new; it has been used previously in the design of optical communication links.

The assumption of a Gaussian beam with obscuration requires a more accurate formula for the pointing loss, $\ell_p(\theta)$, which is the ratio of beam intensity at angle θ off the beam axis to the intensity on the beam axis. The exact equation for $\ell_p(\theta)$ is a ratio of two integrals that cannot be reduced to closed form and, consequently, have to be evaluated numerically. However, because the Taylor series for the ratio of the integrals converges rapidly, the first few terms of the series yield a formula more accurate than the traditional approximation. The new formula is

$$\ell_p(\theta) = [1/f_0^2(\gamma)]\{f_0(\gamma) + [f_2(\gamma)/2!](\pi D\theta/\lambda)^2 + [f_4(\gamma)/4!](\pi D\theta/\lambda)^4 + [f_6(\gamma)/6!](\pi D\theta/\lambda)^6 + \ldots\}^2$$

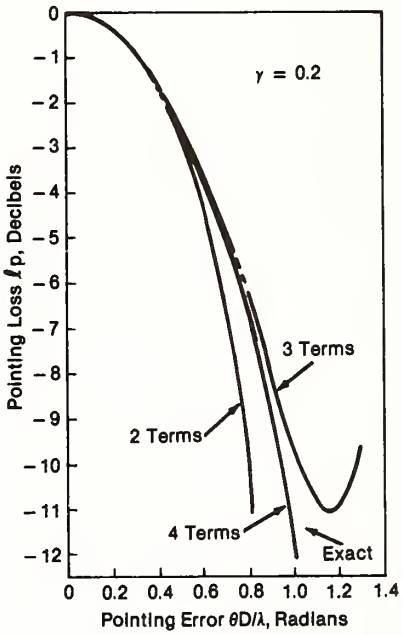
where the coefficients f_i are the ith derivatives of

$$\int_{\gamma^2}^{1} [\exp(-\alpha^2 u)]J_0(\pi D\theta u^{1/2}/\lambda)du$$

with respect to $(\pi D\theta/\lambda)$ evaluated at $\theta = 0$. These coefficients can be evaluated from closed-form expressions for the derivatives or interpolated from tables of coefficients precalculated for $\gamma = 0.0$, 0.1, 0.2, 0.3, and 0.4.

The pointing error of a telescope with $\gamma = 0.2$ was calculated both exactly by evaluation of the complete integrals and approximately by the new formula (see figure) using two, three, or four terms. With only four terms, the result of the new formula lies within 0.1 dB of the exact result for all $\theta D/\lambda \lesssim 0.9$.

This work was done by William K. Marshall and Brian D. Burk of Caltech for **NASA's Jet Propulsion Laboratory**.
NPO-17105 /TN



The **Pointing Loss** given by the new formula converges rapidly toward the exact value as more terms of the Taylor series are included.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Pulsed Source of Energetic Oxygen Atoms

Oxygen molecules are dissociated by an infrared laser beam.

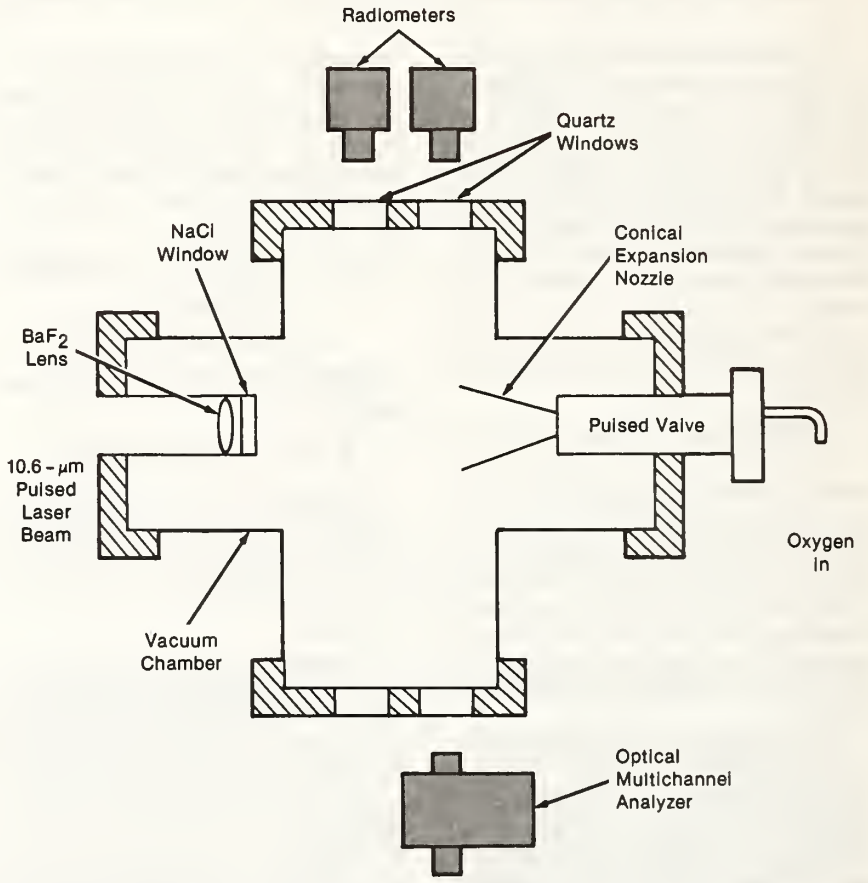
An apparatus has been developed that generates high-flux pulses of oxygen atoms to bombard specimens in experiments on the aging and degradation of materials in a low Earth-orbit environment. The intense atomic oxygen pulses may also be useful in studies of microfabrication techniques.

Within the vacuum chamber of the apparatus (see figure), oxygen gas at a pressure of several atmospheres is introduced into the throat of a conical expansion nozzle through a pulsed valve. After the nozzle is partially filled with gas, the output of a 10-J pulsed CO_2 TEA laser is focused through a BaF_2 lens into the nozzle throat to increase the enthalpy of the flow.

Approximately one-third of the laser energy is delivered in a 200-ns gain-switched spike and induces a breakdown in the high-pressure oxygen near the throat. The resulting plasma continues to absorb the remaining energy in the tail of the 2-μs laser pulse. The rapidly expanding plasma generates a blast wave that propagates through the remaining gas within the nozzle and converts the stagnation energy of the plasma into directed kinetic energy in the exhaust gas.

The nozzle is designed to allow an expansion that favors electron/ion recombination but not the recombination of oxygen atoms into molecules. As the gas expands, the temperature (random kinetic energy) and density decrease as the directed kinetic energy increases. Thus, a cold (low spread in random velocity), high energy beam of oxygen atoms flows out of the nozzle. Under typical operating conditions, the absorption of 5 J of lasser energy into approximately 10^{-4}g of molecular oxygen produces a pulse of approximately 4×10^{18} oxygen atoms with a directed kinetic energy of 5 eV. Operation at pulse repetition rates to 10 Hz has been obtained.

Two kinds of optical measurements have been made to characterize the oxygen-atom pulses. Time histories of the 777.3-nm spectral line of atomic oxygen have been measured by identical radiometers at two different positions along the beam to determine the velocity of the beam. Thus far, velocities from 5 to 13 km/s have been measured. Spectral measurements of the beam have been recorded with a gated optical multichannel analyzer and show no evidence of ionic or molecular oxygen. Preliminary studies of specimens irradiated with atomic oxygen have provided spectral evidence of erosion, in addition to measurable mass loss.



A **Puff of Oxygen Gas** is irradiated by an infrared pulse from a CO_2 laser. The irradiated gas becomes a plasma, which expands in the conical nozzle to produce a pulse of oxygen atoms.

This work was done by George Caledonia, Robert Krech, David Green, and Anthony Pirri of Physical Sciences, Inc., for **NASA's Jet Propulsion Laboratory.**

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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NASA Tech Brief
National Aeronautics and Space Administration

Computer Software

Rational-Spline Subroutines

Smooth curves can be drawn among plotted data more easily.

Scientific data often include random errors that make plotting and curve fitting difficult. The Rational-Spline Approximation with Automatic Tension Adjustment algorithm leads to a flexible, smooth representation of experimental data. As used here, "tension" denotes a mathematical analog of mechanical tension in a spline or other mechanical curve-fitting tool, and "spline" as used here denotes a mathematical generalization of such a tool.

The user sets the conditions for each consecutive pair of knots, which are user-defined divisions in the set of data. These conditions are set to apply no tension, to apply fixed tension, or to determine tension with a tension-adjusting subalgorithm. The user also selects the number of knots, the abscissas of the knots, and the allowed maximum deviations from line segments. The selection of these quantities depends on the actual data and on the requirements of a particular application.

This program differs from the usual spline under tension in that it allows the user to specify different values of tension between adjacent pairs of knots rather than a constant tension over the entire range of data. The subroutines use an automatic adjustment scheme that varies the tension parameter for each interval until the maximum deviation of the spline from the line joining the knots is less than or equal to an amount specified by the user. This procedure frees the user from the drudgery of adjusting individual tension parameters while still giving control over the local behavior of the spline.

The Rational Spline program is written completely in FORTRAN for implementation on a CYBER 850 operating under NOS. It has a central-memory requirement of approximately 1,500 words. The program was released in 1988.

This program was written by James R. Schiess and Patricia A. Kerr of **Langley Research Center** *and Olivia C. Smith of Computer Sciences Corp.*
LAR-13694/TN

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NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Licensing Opportunity

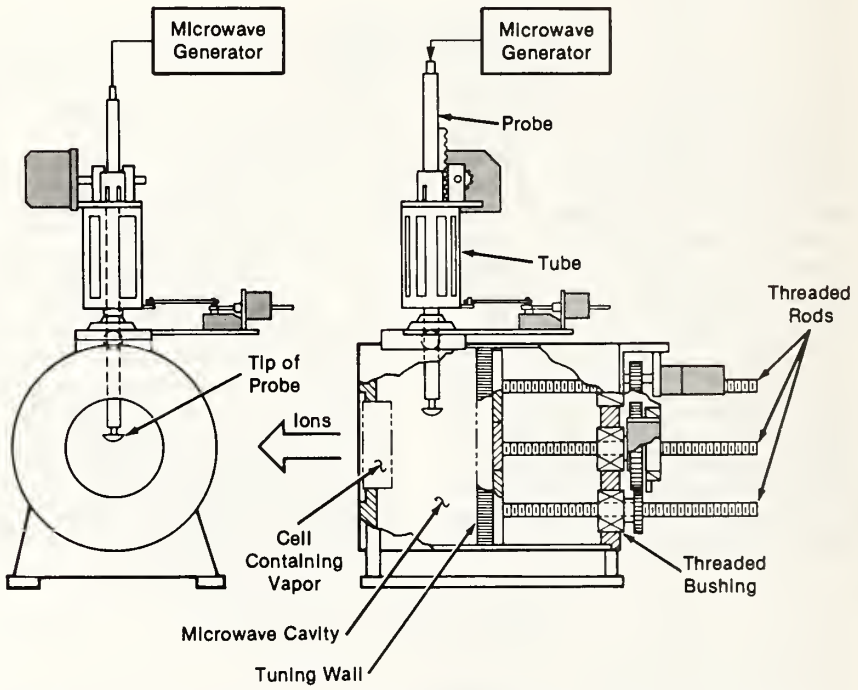
Tunable Microwave Cavity for Ion Source

Positions of components are adjusted for resonance.

A tunable microwave cavity can be used to ionize a gas or a metal vapor to provide a source of ions. Such methods as direct-current (dc) cathode discharges, radio-frequency (RF) induction, and microwave resonance in cavities have been used to generate gaseous plasma discharges, from which ions have been extracted to produce ion beams. All of these approaches have certain disadvantages. In the dc method, cathodes that are heated to emit electrons are subject to sputter erosion and chemical deterioration. Over time, the RF-induction method produces changes in operating characteristics due to the deposition of sputtered films of conductive material on components used in the process.

In the microwave-resonance/tunable-cavity method, RF energy is injected into a cavity and produces a plasma in a cell that contains vapor at one end of the cavity. This is an electroless discharge without the disadvantages of the dc-cathode-discharge and RF-induction methods. However, it is extremely difficult to tune the microwave cavity to resonance because it is necessary to position an RF coupling tip precisely within the cavity. The required position depends on such factors as the dimensions of the cavity and the type and amount of vapor to be used.

To achieve precise positioning, a coaxial probe extends into the microwave cavity through a tube (see figure). One end of the tube is retained in a spherical joint in the cavity wall so that the probe can be pivoted. The probe can be slid in the tube to extend or retract it as needed. Mechanisms are provided for moving the tube in both a side-to-side and back-and-forth motion.



A **Movable Probe and a Tuning Wall** are adjusted to obtain resonance at the microwave frequency used to generate a plasma in a cell at one end of a microwave cavity.

A tuning wall in the cavity is moved by threaded rods extending through threaded bushings, which are geared together. Thus, the rotation of one of the bushings causes the other bushings to rotate simultaneously, thereby positioning the tuning wall precisely.

This work was done by Shigeo Nakanishi, Frank S. Calco, and August R. Scarpelli of **Lewis Research Center**. *No further documentation is available.*

This invention has been patented by NASA (U.S. Patent No. 4,642,523). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Lewis Research Center Refer to LEW-13935/TN

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NASA Tech Brief
National Aeronautics and Space Administration

Three-Dimensional Complex Variables

Recent theoretical advances are reported.

A report presents some results of a new theory of analytic functions of three-dimensional complex variables. Mathematicians have long been frustrated in the search for a three-dimensional system of complex variables that would correspond closely to the well-known two-dimensional complex-number system. While the new three-dimensional system is subject to more limitations and is more difficult to use than is the two-dimensional system, it may nevertheless be useful in the analysis of three-dimensional fluid flows, electrostatic potentials, and other phenomena involving harmonic functions.

The author defines a three-dimensional complex number $Z = x + \delta y + \varepsilon z$, where x, y, and z are customary two-dimensional complex numbers and 1, δ, and ε are the basis vectors of the three-dimensional space, with 1 being the identity element of the algebra. The rules of multiplication are defined by

$$\delta^2 = -\tfrac{1}{2}(1 + i\varepsilon),$$
$$\varepsilon^2 = -\tfrac{1}{2}(1 - i\varepsilon),$$
$$\delta\varepsilon = \varepsilon\delta = -\tfrac{1}{2}(i\delta)$$

where $i^2 = -1$. An important property of the algebra, therefore, is that all elements commute in multiplication.

The general set of three-dimensional complex numbers is denoted as C_3. It is also useful to define the more restricted set, C_3', for which x, y, and z are real numbers. The author presents several theorems and derivations relating to numbers and functions in C_3 and C_3'.

An important item concerns the multiplicative inverse, Z^{-1}: one of the peculiarities of this three-dimensional system is that Z^{-1} is undefined for some nonzero values of Z. In C_3', it is defined everywhere except along six rays (two of which form the y axis) spaced at equal angles in the plane $x = 0$.

The author defines $\bar{Z}$, the "bijugate" of Z in C_3, by the equation

$$\bar{Z} = \tfrac{1}{2}x - \delta y - \varepsilon z$$

The bijugate is somewhat analogous to the two-dimensional complex conjugate. In a theorem that states the necessary conditions for the three-dimensional analyticity of a function $\bar{G} = F(Z)$, the bijugate plays a role analogous to that of the two-dimensional complex conjugate in the Cauchy-Riemann analyticity conditions for two dimensions. Furthermore, as it would be in two dimensions, G is an irrotational and solenoidal vector in three dimensions.

A corollary of the analyticity theorem states that if $\overline{W} = dF/dZ$, then W is also an irrotational and solenoidal vector. Under suitable conditions, the harmonic real or imaginary parts (in the customary two-dimensional-complex sense) of the components of G can be related to a three-dimensional velocity potential and to general three-dimensional stream functions.

This work was done by E. Dale Martin of **Ames Research Center**.

"A System of Three-Dimensional Complex Variables," ARC-11756/TN

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NASA Tech Brief
National Aeronautics and Space Administration
Licensing Opportunity
Ames Research Center, Moffett Field, California

Photometer Tracks the Sun

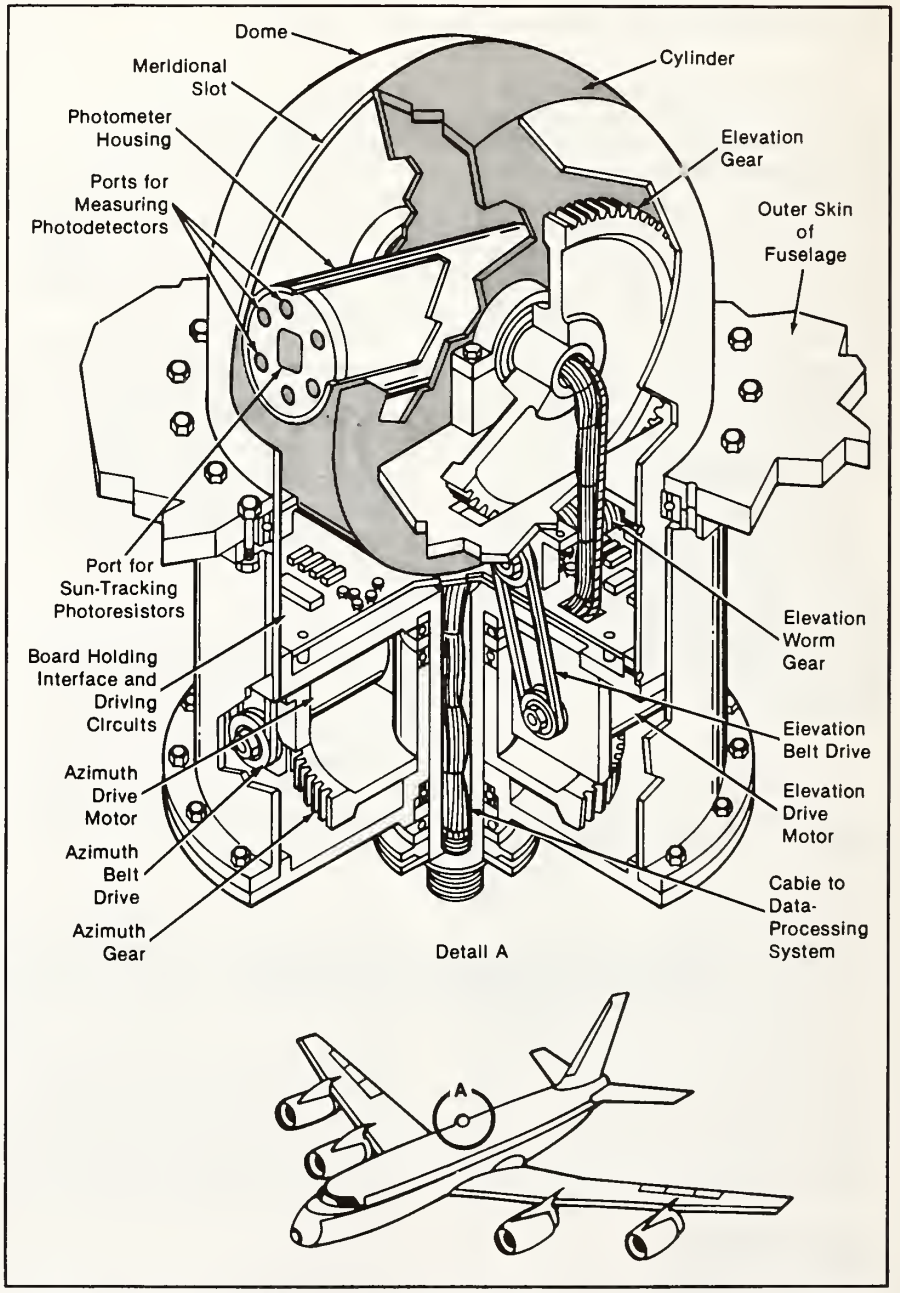
An instrument is designed for use aboard an aircraft.

An airborne Sun-tracking photometer enables observations of the Sun to be made during a much greater portion of flights than was previously possible, without special maneuvers of the airplane. Instead of being mounted in an airplane and viewing through a cabin window like previous photometers, the new instrument occupies a dome atop the airplane (see figure). Rotatable over wide azimuth and elevation ranges, the new instrument commands a far larger range of views than was possible through a cabin window. Moreover, the new instrument can be calibrated without removing it from the airplane. The previous instrument and its window had to be removed for calibration after every flight.

The photometer assembly is mounted in a cylinder in the dome. The elevation drive motor, acting through a belt-and-gear connection, rotates the cylinder in a meridional slot to the desired elevation. In a similar manner, the entire dome is rotated to the desired azimuth angle by the azimuth drive motor through a belt-and-gear linkage.

The photometer housing contains six round ports for its six measuring photodetector channels and a square port for four Sun-tracking photoresistors near its exterior end. A transparent optical flat isolates the atmosphere inside the photometer housing. The Sun-tracking photoresistors are parts of a feedback loop that controls the elevation and azimuth of the photometer so that the photometer housing points toward the Sun. The electronics for the control system are located in the dome. The data from the six photodetector channels are sent to the computer located inside the aircraft passenger area.

A resistance heater in the photometer housing maintains a nearly constant temperature for the photodetectors. The optical flat is exposed to outside air at temperatures as low as −60 °C. To prevent the flat from fogging because of internal moisture, dry nitrogen is circulated inside the photometer housing.



A **Fiberglass Dome Protects a Photometer** and rotates to aim the photometer in azimuth and elevation to track the Sun. The dome provides a controlled environment for the instrument, including its mechanical and electronic parts.

This work was done by Tak Matsumoto, Cesar Mina, Philip Russell, and William Van Ark of **Ames Research Center**. *For further information, Circle 240 on the Reader Service Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center.
Refer to ARC-11622/TN

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

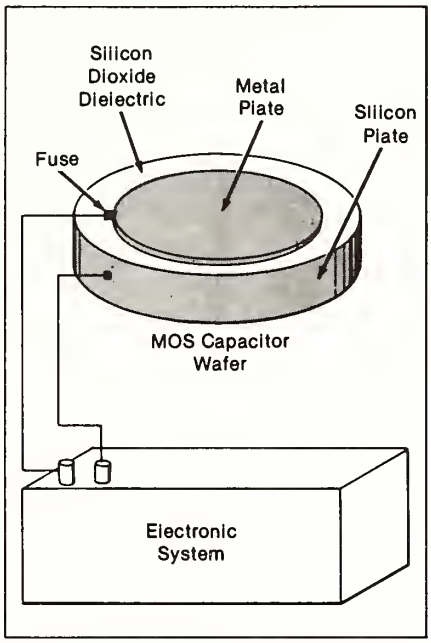
Detecting Space Dust Particles

The precise times of specific impacts are measured.

A new technique records the times the specific craters are formed in targets exposed in space and permits the determination of the direction in which the impacting particles were traveling at the times of the impacts. After recovery of the targets from space, the compositions of the impacting particles can be established through post-flight laboratory analyses of the residual materials in the craters. On Earth, the technique may have industrial and military uses in the detection of fragments driven by explosions.

The principal parts of the device developed for this purpose (see figure) include a metal-oxide/silicon (MOS) capacitor; an electrical circuit, including a fuse, connected to the metal front plate of the MOS capacitor and the silicon-wafer substrate that forms the other plate of the capacitor; and an attached electronic system capable of maintaining a charge on the capacitor and capable of recording the precise time of discharge. The silicon dioxide layer grown on one surface of the silicon wafer is the dielectric of the capacitor.

A hypervelocity particle striking the electrically charged MOS capacitor produces a temporary conducting path between the metal front plate and the silicon substrate, initiating the discharge of the capacitor. With the proper relationship set between the energy stored in the capacitor and the thickness of the metal plate, the current density in the conducting path is sufficient to burn away the metal plate from a substantial region surrounding the impact crater. The removal of the metal around the conducting region terminates the discharge process.



The **MOS Capacitor** is short-circuited by the impact of a particle striking it at high speed.

When the attached electronic system attempts to recharge the capacitor, the recharge current blows the fuse, preventing recharge. (A built-in current-limiting device ensures initial charging of the capacitor.) Any particle impacts that occur when the capacitor is uncharged do not cause the removal of metal from the crater region: thus, the recorded impact time can be related to a single, specific, readily identifiable crater. The direction of the particle at time of impact is established by the known orientation of the MOS capacitor wafer on the spacecraft at the recorded impact time.

In addition to the study of space dust, studies of the orbital dynamics of particles produced by solid-propellant rocket-motor firings in space can be made using this technique. Because only one impact time can be recorded per capacitor, the total number of impact times recorded is a function of the number of individual capacitors flown. Large detection areas can be obtained by using multiple MOS capacitor wafers or by masking the front metal plates on a single MOS wafer to form multiple capacitors.

This work was done by William H. Kinard, Donald H. Humes and Philip C. Kassel, Jr., of **Langley Research Center**, *Jim Wortman of North Carolina State University, and S. Fred Singer and John Stanley of the University of Virginia. No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center
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Transportation & Components

0242 Computerized Analysis of Helicopter-Rotor Aeroelasticity—A computer program generates and solves the equations of aeroelasticity.

0243 Divergent-Trailing-Edge Airfoil—A wedge concept is integrated into basic airfoil design. (Licensing Opportunity)

0244 Rim-Supported Turbine Seal—An interstage seal would accommodate a large pressure drop across a vane stage. (Licensing Opportunity)

0245 Yaw Control at High Angles of Attack—Hinged, conformal forebody strakes provide control when rudders become ineffective. (Licensing Opportunity)

NASA Tech Brief
National Aeronautics and Space Administration
Ames Research Center, Moffett Field, California

Computerized Analysis of Helicopter-Rotor Aeroelasticity

A computer program generates and solves the equations of aeroelasticity.

The analysis of the aeroelastic stability of a helicopter rotor has been automated to a degree. The symbolic-manipulation program, HESL, written in FORTRAN, is used to aid in the derivation of the governing equations of motion for the elastic-bladed rotor. The symbolic program can operate both on expressions and matrices. By transferring some of the burden of algebraic manipulations from the human analyst to the computer, the program reduces both the tedium of the analysis and the consequent opportunity for errors.

In the mathematical model of the helicopter rotor, the blades undergo coupled bending and torsional deformations. The interactions between the blades and the airflow are treated by two-dimensional quasi-steady aerodynamics below stall. Although reversed-flow effects are neglected, unsteady effects, modeled as dynamic inflow, are included.

Using a Lagrangian formulation, the governing equations are derived in generalized coordinates with the help of the symbolic program. The symbolic program generates the steady-state and perturbation equations and writes them into FORTRAN subroutines. These subroutines are called by numerical routines, and the equations are solved numerically. The computer implementation of this procedure consists of three stages (see figure): (1) the symbolic derivation of equations, (2) the coding of the equations into subroutines, and (3) the numerical study after identifying mass, damping, and stiffness coefficients for each equation.

For the case of hovering flight, the equations of motion of the blades and the equations of fluid dynamics that describe the inflow are converted to equations in a multiblade coordinate system by rearranging the coefficients of the equations. For the case of forward flight, the multiblade equations are obtained through the symbolic program. However, the study of forward flight indicates that, for a large number of degrees of freedom and for nonlinear models, the amount of input data required by the symbolic program increases exponentially, making it inconvenient to consider explicitly the harmonic and multiblade equations. Yet, a combination of symbolic and numerical programs at the proper stage in the derivation process makes it effective and beneficial to obtain the numerical results of an analysis of stability by use of this approach. The final multiblade equations are capable of accommodating any number of elastic-blade vibrational modes.

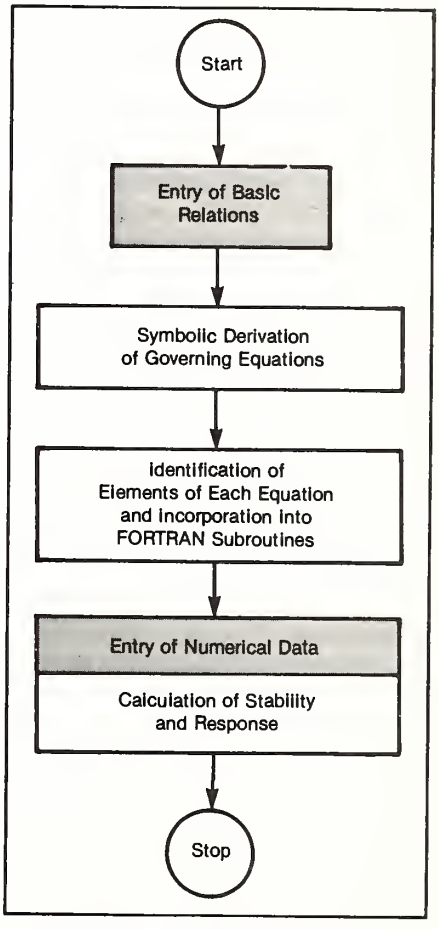
The computerized analytical procedure has been applied to rigid-blade lag-flap, elastic flap-lag, flap-lag-torsion, and quasi-static-torsion rotor-blade models.

The numerical results for hovering flight indicate that dynamic inflow increases the lead-lag regressing-mode damping for torsionally rigid blades. For torsionally flexible blades, the dynamic inflow effect depends on the elastic coupling parameter. For zero elastic coupling, dynamic inflow increases the modal damping. For full elastic coupling, it decreases the damping. This implies that, at some value of the elastic-coupling parameter, the effects of dynamic inflow are negligible.

The numerical study for forward flight indicates that dynamic inflow changes the magnitude of the predicted damping, yet it exerts little influence on damping trends with variations in the advance ratio or in the elastic-coupling parameter for torsionally flexible blades.

This work was done by T. S. R. Reddy of **Ames Research Center**. *Further information may be found in NASA TM-86750 [N87-24455/NSP], [price code A02] "Symbolic Generation of Elastic Rotor Blade Equations Using a FORTRAN Processor and Numerical Study on Dynamic Inflow Effects on the Stability of Helicopter Rotors."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. ARC-11809/TN


Start
Entry of Basic Relations
Symbolic Derivation of Governing Equations
Identification of Elements of Each Equation and Incorporation Into FORTRAN Subroutines
Entry of Numerical Data
Calculation of Stability and Response
Stop

The **Analysis of Aeroelasticity** of the helicopter rotor is a semiautomatic process in which the computer helps to derive the equations, then solves them numerically.

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NASA Tech Brief

National Aeronautics and Space Administration

Langley Research Center, Hampton, Virginia

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Divergent-Trailing-Edge Airfoil

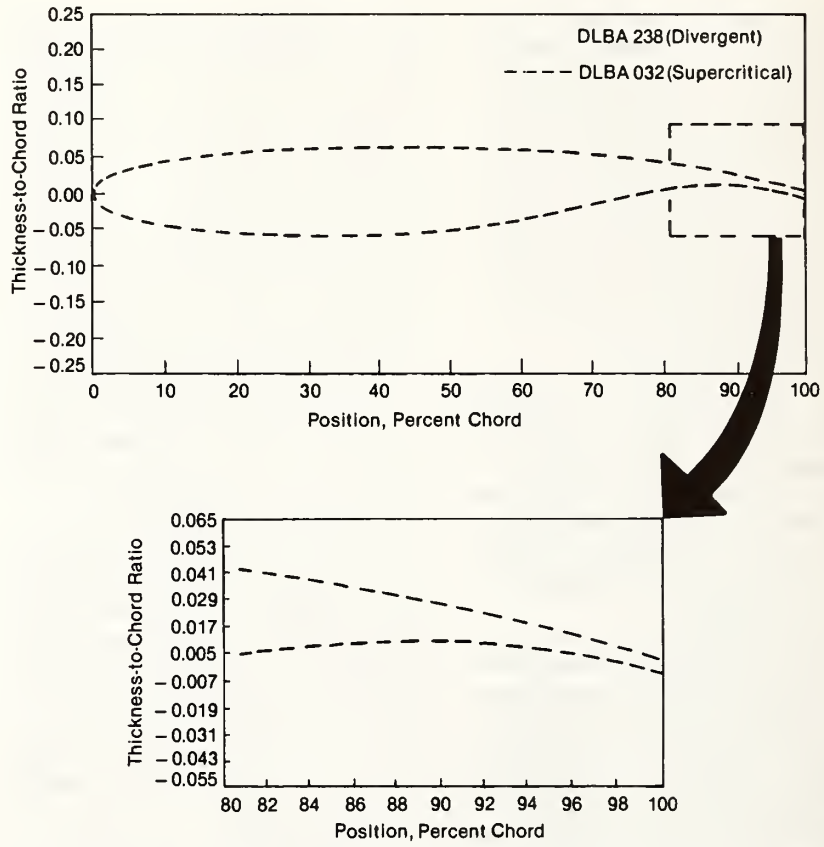
A wedge concept is integrated into basic airfoil design.

In previous studies, tests of high-speed airfoils revealed the possibility of significant airfoil technology improvements through the application of trailing-edge design criteria different from those currently used. Small wedges were added to the airfoil lower-surface trailing edges, thereby producing significant increases in effective camber and an attendant compressibility-drag reduction. However, the wedge addition also introduced a base-drag penalty because of increased airfoil trailing-edge thickness. At the same time, design studies identified difficulties associated with flap structural-design constraints due to the supercritical airfoil thin aft end.

The current airfoil design, DLBA 238, was developed to produce an airfoil with superior geometric characteristics and equivalent cruise aerodynamic characteristics when compared to the baseline supercritical airfoil DLBA 032. The "trailing-edge wedge" concept, briefly investigated in previous studies, has been improved by integration into the basic airfoil design for the DLBA 238. In this design, the trailing-edge thickness and maximum thickness were constrained to be the same as those of the baseline DLBA 032. Hence, the base drag-penalty of a wedge is avoided. Additionally, the airfoil upper-surface geometry was held fixed.

The effective camber increase of the divergent trailing edge was offset by increasing the airfoil depth from approximately 50-to 95-percent chord along the lower surface. This increased depth is a significant structural benefit because this is the region of the wing that sets the flap and aileron structural depth. The figure shows geometric comparisons of the airfoil sections. The resulting divergent trailing edge is quite evident. In the flap spar region, the airfoil depth has been increased by 30 percent. Some depth is lost between 95-percent chord and the trailing edge. The resulting thickness is still considered quite reasonable.

Calculated upper-surface pressure distributions are nearly the same for both airfoils. The only notable exception is that the DLBA 238 recovers to a slightly lower pressure at the upper-surface trailing edge. However, a considerable difference is noted in the lower-surface pressure distributions. Increased velocities from approximately 56- to 94-percent chord relate roughly to the region of increased airfoil depth. The lower recompression gradient is nearly linear. Calculated drag-rise characteristics for the two airfoils are, by design, essentially the same, and calculated lift, drag, and pitching-moment characteristics of the two airfoils are quite similar at 0.74 mach. Experimental drag-rise characteristics show a slight drag benefit for DLBA238.



The **Divergent-Trailing-Edge and Supercritical Airfoil** shapes differ most prominently in the trailing-edge region. The divergent airfoil has cruise aerodynamic characteristics essentially equivalent to those of the supercritical airfoil.

This work was done by Preston A. Henne and Robert D. Gregg of McDonnell Douglas Corp. for **Langley Research Center**. *No further documentation is available.*

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C 2457(f)], to the McDonnell Douglas Corp. Inquiries concerning licenses for its commercial development should be addressed to

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Rim-Supported Turbine Seal

An interstage seal would accommodate a large pressure drop across a vane stage.

A proposed interstage seal for a turbine would be supported by the rim of the turbine disk. The seal concept was developed for such small rocket turbines as liquid-oxygen pumps. Usually, interstage seals in these turbines are positioned by snap lands and held in place by tie bolts. The new seal would reduce the number of parts and simplify the rotor configuration.

The seal concept would keep diaphragm-type areas small and thus ensure low axial loads on vanes, because the sealing surfaces are close to the innermost gas-flow path. It is thus well suited to turbines with high pressure drops across vane stages.

In the seal configuration shown in the figure, two blade stages would be supported by a single disk, which is broached over the entire width of the rim. Although a full ring seal is envisioned, segments could be used, as many as the number of blades if necessary.

This work was done by Kent O. Longenecker of United Technologies Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center
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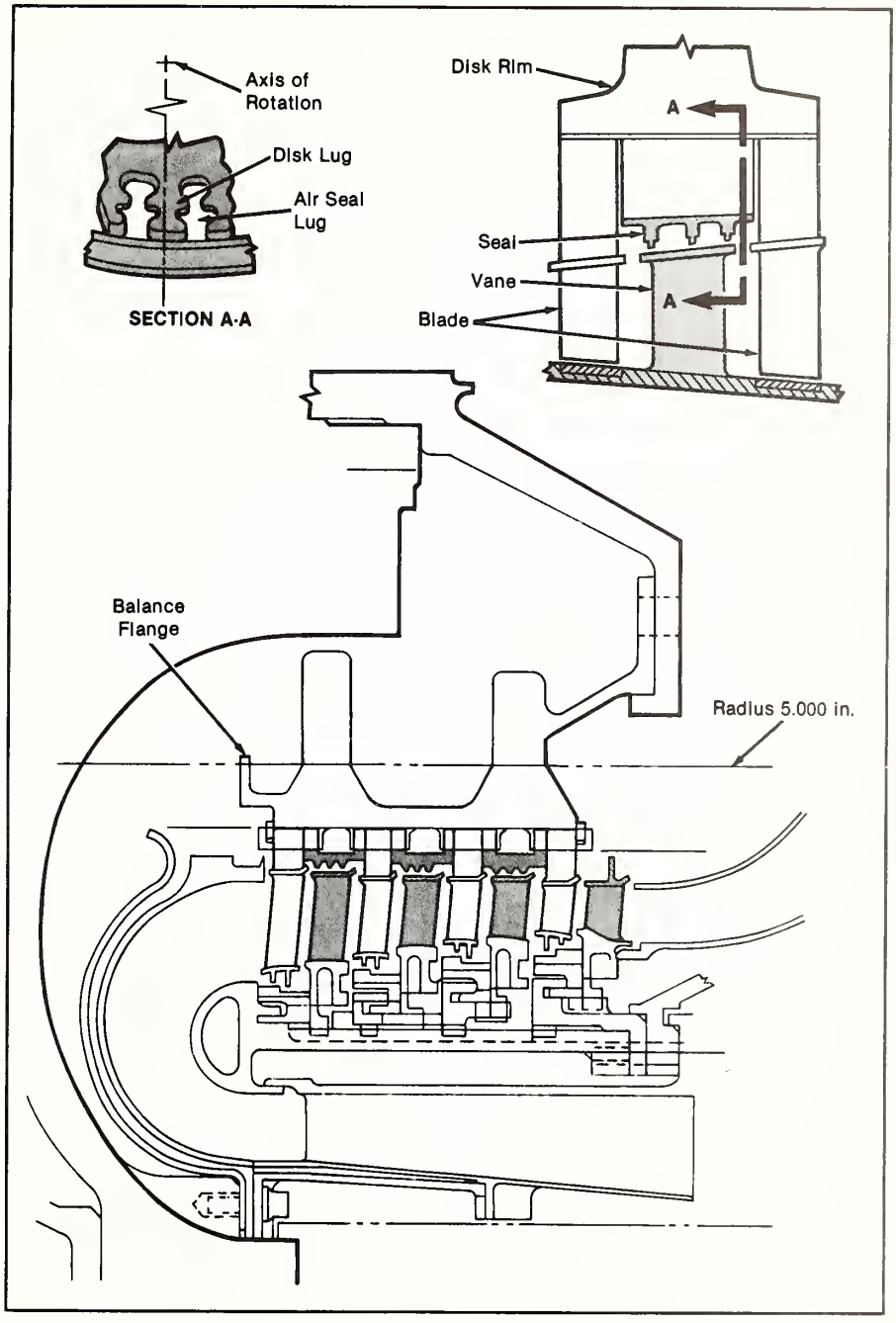

The **Sealing Surfaces Are Close** to the inner diameter of the gas-flow path.

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NASA Tech Brief

National Aeronautics and Space Administration

Langley Research Center, Hampton, Virginia

Licensing Opportunity

Yaw Control at High Angles of Attack

Hinged, conformal forebody strakes provide control when rudders become ineffective.

In a conventional airplane, the rudder becomes ineffective when the craft is operating at a very high angle of attack because of massive flow separation on lifting surfaces. The use of articulated, conformal forebody strakes provides yaw control at such high angles of attack.

The device consists of a symmetric pair of longitudinally hinged strakes designed to fold completely into the forebody contour. The strakes can be rotated individually out into the external flow. The selective deployment of one of the strakes forces a stable, asymmetric vortex pattern on the forebody at high angles of attack, thereby generating a sideward force component. The sideward force, acting considerably forward of the craft center of gravity, produces a yawing moment. Reliance on forced asymmetry of forebody-vortex separation allows this yawing moment to continue unabated to high angles of attack, unaffected by flow separation on wings and aft surfaces.

Figure 1 depicts a conformal strake generated by means of an oblique plane intersecting through the upper quarter to one side of the forebody plane of symmetry; a mirror image of the strake geometry is generated on the other side. The strakes are pivoted to rotate about a longitudinal axis contained in the respective intersection planes. Figure 2 shows a typical cross section of the forebody with one strake deployed. The consequent asymmetric separation of the crossflow at high angles of attack produces a skewed pressure distribution around the forebody circumference, which creates a net side force as indicated. Increasing the strake deflection causes progressive side force increments, thus providing a means of yawing moment modulation.

The principle is equally valid, as demonstrated in wind-tunnel tests, for forebodies of triangular and other noncircular cross sections. The forebody sideward force is maintained at angles of attack well above the typical limit of rudder effectiveness. Wind-tunnel tests have confirmed the effectiveness of this arrangement at angles of attack between 10° and 70°, and sideslip angles to 20°.

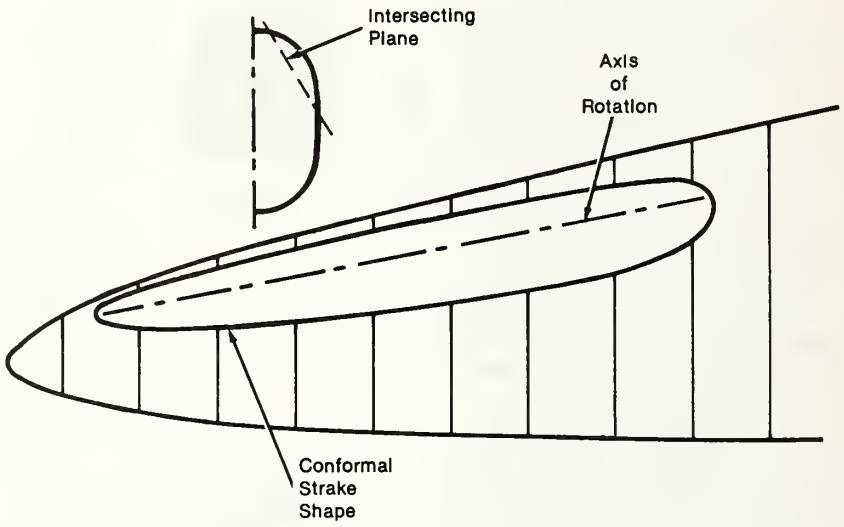

Figure 1. **Conformal Strake Shape** is generated by an oblique plane intersecting the forebody side.

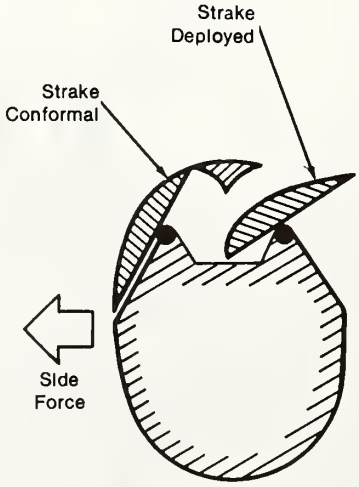

Figure 2. The **Asymmetric Flow** produced by a deployed strake generates a sideward force that causes the aircraft to yaw.

This work was done by Daniel G. Murri of **Langley Research Center** *and Dhanvada M. Rao of Vigyan Research Associates, Inc. No further documentation is available.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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